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DEVELOPMENT AND USE OF TALKING MOTION PICTURES.*

BY

H. M. WILCOX,

Vice President of Electrical Research Products, Inc., Subsidiary of Western Electric Company.

Every improved facility of communication has had a profound influence on civilization. The printing press, the telegraph, the telephone, the radio have each in turn contributed to the welfare of mankind.

The talking motion picture is another useful means of communication, supplementing but not supplanting those already existing. For its emotional effects it appeals to our two most acute and discriminating senses, sight and hearing, and therefore is subject to at least double the hazard of a medium which seeks to satisfy either one individually as lack of coördination may result in a ridiculous effect. But with these hazards overcome it has far more power to rouse us both emotionally and intellectually.

So far its use has been confined largely to entertainment, but as man lives not by bread alone its contribution to the happiness of mankind has not been inconsiderable even in this relatively restricted field. In the presentation of my subject this evening, I shall use the talking motion picture in various forms, and I am confident it will fire your imagination as to its usefulness for educational, social and commercial purposes.

* Presented at a meeting held Thursday March 31, 1932.

(Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

This is a new instrument, a mere infant commercially only five years old, and experience must be gained in its application.

The problems of recording and reproducing are highly technical. They involve the conversion of minute units of energy back and forth, their fixation, their amplification and their final delivery undistorted to one of the most sensitive and discriminating of our senses. Sound waves are converted into electrical energy, thence into mechanical or light energy; then the fixation process, thence back into electrical energy and a final reconversion back into sound. The whole might be considered as a continuous electrical circuit with a delay element, the recording process. To appreciate the problems involved, it is essential to have some understanding of the characteristics of sound and the capacity of the human ear to interpret them.

Sound has its origin in vibrating bodies. The atmosphere exerts a definite uniform pressure on all bodies with which it is in contact. When vibrations have been communicated to the atmosphere they cause rapid fluctuations in this pressure above and below its normal static value. These changes of pressure on the ear result in the sensation which we know as sound.

There are three generally recognized characteristics by which sound is judged by a listener.

Pitch, which is measured by the frequency or number of pulsations per second. The audible range is from about 16 to 16,000 vibrations or cycles per second and is frequently termed the sound spectrum.

Volume or loudness, which is measured in terms of energy intensity or pressure. Since the ear hears logarithmetically this is expressed in terms of logarithmetic units called decibels, one decibel being approximately the smallest change in volume which the ear can detect.

Quality or timbre, which depends upon the presence of overtones of the fundamental frequency, that is, frequencies having two or more times the frequency of the original fundamental note. Timbre is dependent not only on the number of these harmonics or overtones, but also upon the relative intensities with which they occur. Nearly all musical instruments have in

them the same series of overtones but the relative intensities of the individual overtones vary considerably from one instrument to another and it is this that determines the character or personality of the instrument.

In speech the range of fundamentals is relatively narrow, extending from about 100 to 250 cycles for male speech and about 200 to 500 cycles for female speech. It is interesting to note, however, that practically none of the characteristics of speech by which we recognize one articulate sound from another is particularly influenced by these fundamentals. The frequencies which are responsible for our ability to understand articulate speech lie among the harmonics of the fundamental tones. With the vowel sounds some of the frequencies which are characteristic may lie as high as 3,000 to 4,000 vibrations per second. Many of the consonants and particularly the sibilant sounds require as high as 8,000, or more, cycles for their faithful reproduction. It is therefore seen that the frequency range necessary for complete naturalness of speech is approximately 100 to 8,000 cycles. The volume range for speech is not large and may ordinarily be handled without difficulty by a recording and reproducing system.

With music a much wider range of both pitch and volume is necessary. The fundamentals of the bass instruments require frequencies below 40 vibrations per second while the majority of the other instruments, particularly the percussion group, require above 10,000 cycles for faithful reproduction and for bringing out their full emotional musical value. In the case of music the volume requirements are also very severe. A symphony orchestra may easily have an average volume range of 66 decibels with instantaneous peaks of energy up to 75 or 80 decibels.

The tinkling of keys is about the highest pitched sound that the ear can perceive and the rumbling of the lowest organ notes the deepest it can detect, a range of about 9½ octaves. Artillery fire is about the loudest sound the ear can endure while the faint rustling of leaves is about the faintest sound it can detect, an energy ratio of 100 million million to one. Any apparatus which is designed to reproduce all sounds faithfully must be capable of handling a sufficiently wide

range of pitch and volume to produce an illusion of naturalness, must have a delicacy of response sufficient to reproduce the finest shadings which the ear is capable of perceiving and must do this without introducing outside or extraneous sounds.

Although sound had previously been recorded by various methods, Thomas A. Edison was the first to record sound in such form that it could be used again to vibrate a diaphragm and thus reproduce sound. Edison's invention was made in 1876 and patented in 1877.

Prior to this invention, all records of sound had been in the form of a wavy line. Edison's records were on a cylinder with a spiral groove over which was placed a thin sheet of tin foil. A steel stylus was attached to a drum head of gold beaters skin and as the cylinder was rotated the vibrations of the diaphragm served to impress through the stylus a groove of varying depth into the tin foil. When allowed to again traverse this groove the same device emitted a barely recognizable reproduction of the sound.

Bell and Taintor later studied this method and concluded that the rubbing process had to be abandoned and an engraving process substituted, that is, instead of pushing the surface of the record down in a spiral groove it was necessary that the material be dug out or engraved into the record. As a result of their experiments they obtained a patent in 1886, and issued the graphophone in 1887, the first practical apparatus of the phonograph type.

In 1887 Emile Berliner, who had been concerned in the early developments of the telephone, patented the gramophone. He concluded that the forces required to cut a groove of varying depth were much greater than those available in the human voice, so he returned to the earlier ideas and proceeded to make a lateral cut record. He also concluded that it would be more convenient if these records were in flat or disc form. Berliner cut the record from below so that the material removed would fall away while the record was being cut and then etched the disc chemically. Later the substitution of an electroplating process in place of the etching made this form of duplication the type commonly used commercially.

All the earlier attempts to record and reproduce sound by mechanical methods suffered under the limitations imposed

by the minute power of the originating source, the inertia of the apparatus itself, and the unnatural conditions under which the recording artists were forced to work. It was not until electrical transmission and amplification of sound as developed in the telephone were applied to recording and reproduction that a product of commercial quality and amplitude was obtained. Hence the invention of the telephone in 1875 by Alexander Graham Bell is one of the most important progenitors of the talking picture.

Of all the inventions utilized in sound recording and reproduction perhaps the most vital is the vacuum tube, as it provides power. Its property of unlimited amplification without change in the characteristics of an electrical current made possible the long distance telephone, brought the radio into existence and overcame the mechanical limitations of the old acoustic phonograph. It was in October 1912 that Dr. Lee DeForest, after several years of research and experimentation, brought his patents to the Bell Laboratories and made a demonstration of his three-element audion. The performance of these tubes was far short of the requirements for handling loads comparable to those in commercial telephone circuits, but Dr. Arnold of the Laboratories quickly diagnosed the trouble as arising from the erratic effects resulting from gas ionization within the tube occurring at higher voltages, and concluded that a commercially successful telephone repeater could be made from the DeForest audion if the gas were removed and the audion converted into a vacuum tube.

The transformation of Dr. Bell's original fundamental invention into the transcontinental long distance telephone was brought about not by the inventive genius of one man but was effected through the medium of organized research, through the efforts of many men. Dr. Bell's original little workshop grew into a great research organization, the Bell Telephone Laboratories. This organization was continuously working to extend the telephone technique, which heretofore had been limited to the transmission and reception of commercially intelligible speech requiring a sound spectrum of from 200 to 3,000 cycles and a comparatively restricted volume range to a point where the whole range of audible sound could be encompassed.

During the war the energies of the Bell Laboratories research staff were of necessity directed toward the development of apparatus for war purposes, which included equipment for radio communication and for sensitive, high quality detection of sound. In the course of this work many refinements of the telephone were developed; the telephone transmitter was glorified into the microphone; the telephone receiver had grown into the loud speaker.

Immediately after the war, work was actively resumed on the improvement of sound transmission and reproduction. Resulting from this work there appeared in the next few years voice reinforcing apparatus known as public address systems, high quality broadcasting, electrical recording, and the orthophonic phonograph. Also picture transmission by wire and the printer telegraph had been developed, these involving problems of synchronization similar in many respects to the synchronization necessary in talking pictures.

By 1925 most of the elements for a successful talking picture system were in existence. These basic requirements included:

1. Frequency or pitch range of not less than 100 to 4,500 cycles.
2. Volume or loudness range of not less than 30 to 35 decibels.
3. Ability to pick up sounds at a distance from the performer so that the actor has the necessary freedom of movement to permit natural photography.
4. An easily adaptable means of synchronizing both the recording and reproduction in the taking and projecting of the picture.

By this time the motion picture had become one of the country's large industries. From the nickelodeon and the little store-theatre in the mining and steel centers of Pennsylvania, it had grown in twenty-five years to a rank among the first ten of our large businesses. Its leaders were mostly men of humble origin but with imagination, daring and infinite capacity for hard work. The fascination of the work as well as the large commercial rewards had attracted a young, vigorous and resourceful personnel from all walks of life. I mention this as the type of man power running the motion picture industry was an important factor in the successful revolution

resulting from the adoption of sound which was about to take place and I doubt if any other industry ever endured so complete an upheaval in so short a period.

One may wonder why such a transformation was undertaken. Frankly it was not entirely voluntary and furthermore the completeness of the change and the problems involved were not realized. But something was wrong. For several years the industry had not only not shown any growth, there were indications of actual decline. In looking back the reason now seems quite clear. In endeavoring to supply the quantity of pictures required the material for stories was becoming exhausted and the emotional quality of much of the product was failing to hold audiences. The talking picture opened up an almost limitless supply of new material; speech, music and sound effects. It made available the whole dramatic stage and provided a medium unhampered by many of the limitations of the stage such as space and time and tempo. The story to be told could flow through from beginning to end without interruption, without losing the audience through scene shifting. Its possibilities even yet are barely touched.

In the spring of 1926, the Warner Brothers undertook to utilize this new medium. A makeshift sound studio was established in the old Manhattan Opera House on 34th Street in New York. Seats were removed and the stage built out over the orchestra floor. Recording apparatus was moved over from the Bell Laboratories and there was set up a more or less complete sound system. One box became a generator room, another a battery room; the dressing room of many a former star became a recording room; Oscar Hammerstein's famous reception hall on the second floor became a monitoring and review room. During the summer the complete score for the new silent picture Don Juan starring John Barrymore was recorded; the New York Philharmonic Orchestra played the overture to Tannhäuser; short numbers were made by Marion Talley, Anna Case, Harold Bauer, Martinelli, Mischa Elman; an introductory address by Will Hays was recorded. The Warner Theatre meanwhile was equipped with reproducing apparatus.

On the evening of August 6, 1926, this program was presented to the public in Warners Theatre, N. Y. The effect

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on the audience was startling, and as far as the motion picture industry was concerned, sound came to the silent screen that night.

This first program was recorded entirely on discs similar to the phonograph, only larger and revolving more slowly, so that one record could play the ten minutes required to project one reel, approximately 1,000 feet, of picture. In January, 1927, William Fox showed sound recorded on film and followed soon with the first Movietone news reel. The following October Warners presented Al Jolson in "The Jazz Singer," which incorporated the first use of dialogue in a full length feature picture.

By 1928 the rest of the motion picture industry were confronted with the alternatives of "going talkie" or seeing Warner and Fox run off with their business. These two had dared risk a substantial investment by making sound pictures with very few theatres equipped to show them and about 150 theatre owners had gambled $10,000 to $20,000 each in equipping their theatres to show talking pictures. But the response of the public indicated that the vicious circle was broken. In May the industry took the plunge. The question was not "How much will it cost?" but "How soon can it be done?" By midsummer 5,000 men were at work in the telephone plant of the Western Electric Company in Chicago manufacturing equipment, while fully as many more were engaged in building and equipping sound stages at the studios in Hollywood and in installing reproducers in theatres.

After construction came the development of studio technique, which involved problems from the selection of the story and the writing of the scenario clear through to the final completed picture. There was no time for laboratory experimentation and the technique of using this new instrument had to be developed under the pressure of actual commercial production. I shall touch briefly on a few of these problems.

The question arose as to the relative merits of disc and film recording. Both technical and commercial considerations were involved. When the talking motion picture was ready for commercial release in 1926, recording on discs and the processing of the records were already an established industry and the facilities of the phonograph companies could be

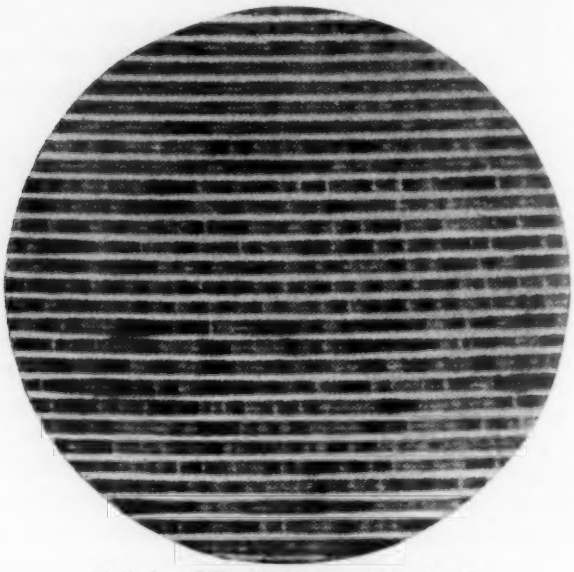
utilized for making records. On the other hand, while film recording was even then fairly well developed in the laboratories it had never been applied commercially and both delay and risk were hazarded if it were adopted. So the disc record was generally adopted at first.

It soon became evident, however, that the cost of distributing pictures would be greatly increased where both film and discs had to be handled and in addition operating difficulties were encountered through careless adjustment of the films and discs on the reproducing machines, resulting in pictures and sound being "out of step" with complete loss of illusion. I remember distinctly at one of the early performances at the Warner Theatre seeing Martinelli appear on the screen singing a banjo solo! Also film records furnish a much more flexible medium, as the film can be cut and patched at will and later after the picture is released any deletions required by the censorship in different states can be readily handled, whereas with disc records this is very difficult or impossible.

To appreciate the technical considerations involved some understanding of the two methods of recording is desirable. Please bear in mind that in either method two dimensions, namely pitch and volume, must be written on a single plane surface.

In disc recording a groove is cut on a soft wax surface by a recording stylus vibrated by amplified sound currents. These vibrations may be either vertical or lateral. Edison's original method employed the vertical method, which has since been termed "hill and dale" recording. Here the center line of the groove is a perfect spiral while the vibrations are recorded by varying the depth of the groove. In lateral recording the depth of the groove remains constant while the vibrations of the recording stylus are imprinted in the wax in the form of a wavy line through the displacement sideways of the walls of the groove. In both methods pitch is recorded by the number of vibrations imprinted per revolution on the wax matrix while volume is recorded by the velocity of displacement of the groove, the louder the sound at any given frequency the deeper the cut on vertical recording, or the greater the lateral displacement of the walls of the groove in lateral recording.

FIG. 1.



Vertical cut (hill and dale) disc record (enlarged).

FIG. 2.

Lateral cut disc record (enlarged).

There are also two methods of photographic or film recording known as the variable area type and the variable density type. Fortunately both of these can be reproduced on the same machine without any change in the mechanism, which is not the case with the two types of disc recording. In the variable area method the sound is written by mirror galvanometer as a series of sawtooth valleys and peaks, pitch being

FIG. 3.

Variable area film record (enlarged).

recorded by the number of these in a given length of film, while volume is recorded by their depth or height. The variable density record consists of a series of small parallel lines of varying photographic density and distance apart, the varying degrees of density recording the volume and the distance apart of the striations recording the pitch. This form of record is obtained through the focussing of a bright light through a narrow aperture formed by two tightly stretched wires placed close together in a magnetic field. A variable current representing sound waves converted into electrical energy at the microphone passes through these tightly stretched wires causing them to vibrate in exact conformity to the vibrations of the sound waves. The film negative travels at a constant speed past the aperture and receives the impression in the form of tiny parallel lines of

varying degrees of lightness and darkness and varying distances apart. A modification of this method is to vary the intensity of the light source by connecting the wires leading from the microphone to the terminals of a flashing lamp projecting through a fixed aperture. This is termed the "flashing lamp" method, while the fluctuating wires is called the "light valve" method and is the method utilized in the Western Electric system. Both of these methods of variable density recording are in practical use, the flashing lamp type mainly in news reel work, the light valve mainly in studio work, as

FIG. 4.

Variable density film record (enlarged).

the quality of product has so far proved cleaner and more uniform with the latter owing to the greater intensity of light delivered to the negative so that full exposure of the film can be obtained.

The reproducing process is the reverse of the recording process and bears a resemblance to the radio receiver, differing mainly in the source of the impulse which comes from either a film or disc record instead of from electrical vibrations in the ether. The sound record on the disc vibrates a needle attached to an electro-magnetic device which converts the

vibrations into an electric current. The film record is passed at a uniform speed through a narrow line of bright light, focussed on the sound track. Behind the film is a photo-electric cell. The lines in the sound track interrupting the light reaching the cell generate in the cell a fluctuating current of the same characteristics as the original sound. The current from the reproducer is then amplified, transmitted to the loud speaker and reconverted into sound.

A motion picture is in reality a mosaic, the assembly of a great number of short takes; a series of episodes, each one flowing into the next to make a continuous smoothly flowing story. Though one scene may appear in several different places in a picture, it is obviously economical to build the set once and to take all of the scenes appearing on this set in succession and then later "cut" each into its place in the picture. In fact the final cutting, editing and assembly of a picture is one of the very important operations in its construction. With the advent of sound this method resulted in some difficult technical problems, this being particularly the case with disc recording.

One of the serious problems encountered was that of maintaining a uniform recording level when adjacent scenes in a picture may have been taken weeks apart. It is obviously too much to ask the thousands of operators in theatres to continuously manipulate the reproducer levels to compensate for varying recording levels. In fact, it is essential that the human element in reproducing be eliminated as far as possible and that all of the shadings of loudness or softness be incorporated in the original film and that little or nothing be left to the discretion of the theatre operator in playing. To meet this difficulty an operation known as "dubbing" or re-recording had to be perfected and adapted to talking pictures. This consists of running the final assembled picture through a reproducing system, the output of which is connected to a recording machine instead of to loud speakers. While the picture is being thus run the output levels from the reproducing machine can be adjusted at will, incidental sounds separately recorded can be superimposed and a re-recorded picture produced which incorporates all of the shadings of sound and any special sound effects desired by the producer or

director and which can be reproduced from beginning to end with but a single setting of volume level in the theatre.

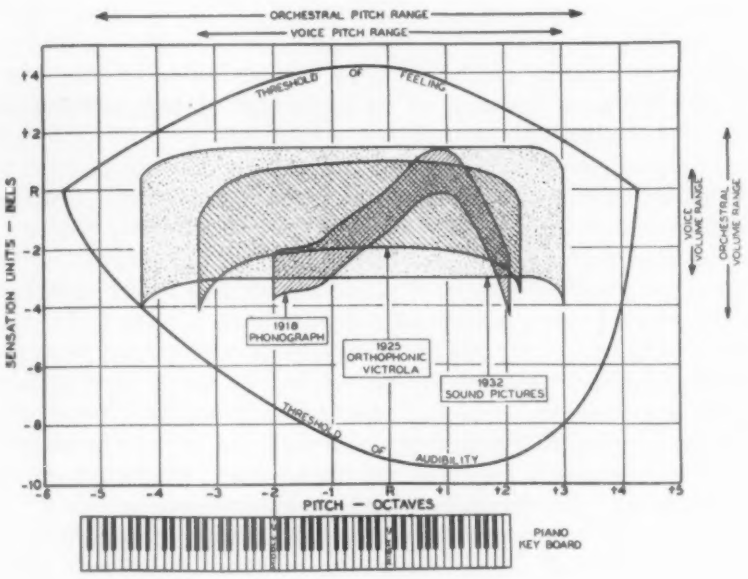
To obtain a satisfactory sound record on film it is necessary to exercise a considerable degree of technical control of the developing and printing processes and to operate under formulæ maintained within certain permissible variations. It was found that there was little or no standardization in the developing and printing formulæ as related to the picture and that the control of processes in the film laboratories was not particularly close. Camera men are artists who are painting a picture on a photographic film and each one has his own theories in regard to lighting, picture density and contrasts. It was necessary to evolve printing and developing formulæ which would satisfy the photographic requirements, leaving a large degree of license to the camera man, and at the same time produce a satisfactory sound negative and print. In addition, close technical control of the developing and printing processes in the film laboratories had to be established. At first there was considerable conflict and compromises were necessary but the early concessions have now been largely eliminated leaving the camera man practically as much latitude as he previously had but with the added assurance of more reliable and uniform results in the better operation in the film laboratories.

The experience in acoustics relating to the pickup of sound gained in phonograph recording and in broadcasting studios was applied to the motion picture stage, but it was soon found that where sight is combined with sound many of the old theories of voice input were not directly applicable. It was necessary to conduct an empirical study of the factors of seeing and hearing which coördinate to produce the illusion of naturalness and of perspective and the knowledge thus obtained in the making of sound pictures has been applied beneficially to radio broadcasting studios and other enclosures in which correct acoustics are important.

Early experience with talking picture theatres proved that the acoustic problems were not limited to the studio. The theatre forms an essential element in the reproducing system, linking the loud speaker to the auditor, and in the design of the silent motion picture theatre no thought had been given

to acoustics, and seldom were satisfactory conditions unwittingly obtained. Studies of theatre conditions indicated that both qualitative and quantitative acoustic measurements were necessary if remedies were to be prescribed with any degree of certainty that an improvement would be obtained. This led to the development of the frequency analyzer, the level analyzer, the reverberation meter and the noise meter, which have been successfully used not only in the analysis of acoustic conditions in theatres, but in other fields as well,

FIG. 5.



such as the New York subway, the study of railway structures, the silencing of noisy machines and the correction of auditorium acoustics. The success of the recent piano recital by Paderewski before an audience of 16,000 in Madison Square Garden without the use of any sound amplifying device evidences what can be done by proper acoustic treatment.

Two of the most outstanding improvements which have been effected in the past five years are the obtaining of sound perspective and the elimination of extraneous noise, which on

disc records is termed needle scratch and on film records ground noise.

This so-called ground noise is caused mainly by irregularities in the sound track and would be practically eliminated if the sound track were black during silent periods, thereby cutting off all light from the photoelectric cell. This is effected by making the negative sound track substantially clear during silence through the closing of the light valve slit from a normal opening of one one thousandth of an inch to three ten thousandths of an inch through the medium of a unidirectional biasing current superimposed upon the fluctuating sound current. As the sound currents build up the effect of the biasing current is proportionately neutralized and the light valve operates so that full modulation is obtained without clashing of the light valve ribbons.

This briefly is the story of the talking motion picture to date. Now what of the future? What implication does this medium hold for the field of education and other forms of social endeavor? Is it capable of presenting material which can not be presented equally as well by any other medium? Can certain matters be presented more economically by this method than by any other? Are impressions gained from the talking picture more vivid, more concrete, more lasting than from other media? Would the material which I have presented to you this evening have been equally impressive without Dr. Fletcher's experiments, without Dr. Watson's narrative, without the ten minute trip to Hollywood?

For a little over two years we have been experimenting in coöperation with numerous educators and educational agencies with the use of the talking picture in the educational field. In this connection we have made a number of pictures and conducted a number of rather elaborately controlled field experiments. It has been pretty well determined that the talking picture furnishes a means for the elaboration of the student's environment better than any other medium yet used; it is a powerful stimulant to the imagination and in the the presentation of certain general topics it affects a considerable economy of time. For example in a test conducted recently at Teachers' College, Columbia University, certain highly technical aspects of teacher training were presented by

a twenty minute talking motion picture to one group of students, while another group were permitted to study the monograph from which the picture was made for half a day, but were not shown the picture. The former group made considerably higher scores than the latter on the subsequent test. Last, but not least, the talking picture can democratize education in much the same way that it has democratized the dramatic stage and the great teacher can be taken to students in the most remote district and material presented to them which has heretofore been reserved for the chosen few.

We feel that the case of the talking picture as an effective instrument in education has been proved, but the solution of the problems which it presents and its fullest development can come only through the wholehearted coöperation of educators and educational institutions who alone can furnish the insight necessary to complete realization of its potentialities.

PROGRAM OF PICTURES.

1. ACOUSTIC PRINCIPLES OF RECORDING AND REPRODUCTION, by Dr. Harvey Fletcher of the Bell Telephone Laboratories.
2. TELEPHONE MEMORIES, by Dr. Thomas A. Watson, assistant to Alexander Graham Bell at the time of the invention of the Telephone in 1875.
3. A TRIP THROUGH THE PARAMOUNT SOUND PICTURE STUDIO in Hollywood, California.
4. PROGRESS IN RECORDING. Selections from pictures made in 1927, 1929 and 1931.
5. PROGRESS OF TRANSPORTATION, from the Social Science Series of educational pictures.
6. BUTTERFLIES, from the Natural Science Series of educational pictures.
7. STRING CHOIR, from the Music Appreciation Series of educational pictures.

Dichlorodifluoromethane—Freon for Short.—(*Ind. & Eng. Chem.*, **24**, 620.) Dichlorodifluoromethane is an organic compound of synthetic origin and seems to be eminently suitable as a refrigerant. Before its acceptance for such a purpose the product must undergo a very rigid investigation particularly in respect to its possible health hazards. In describing the properties of this product with the multi-syllabic designation P. J. Thompson calls it by a much shorter name: Freon, and thus economizes on many ems of type.

The ideal refrigerant is one neither inflammable nor toxic nor capable of entering into dangerous chemical reactions, which could be operated at relatively low pressures and which would be efficient and suitable for industrial, commercial, apartment house and household refrigerating systems. Freon was developed in a deliberate attempt to produce, by chemical arrangement, a refrigerant from which these hazards are eliminated and which still has properties favorable to economic operation. Freon is a colorless, almost odorless gas and when liquefied, boils at — 21.7° F. To give some idea as to the nature and antecedents of the material let us start with methane, sometimes known as marsh gas, of which Freon is a derivative. Methane consists of a carbon atom to which is attached four hydrogen atoms. If three of these hydrogens are replaced by chlorine the compound chloroform is formed whereas if all the hydrogens are thus replaced we have carbon tetrachloride, commonly known as pyrene. Most of us think of fluorine as combined with hydrogen to give hydrofluoric acid which attacks glass avidly and so must be stored in bottles of wax. Briefly, Freon is prepared by taking carbon tetrachloride and replacing two of the chorine atoms with two atoms of fluorine. Details of the reaction are not disclosed.

Freon leaks are detected by a novel apparatus known as a halide lamp. The lamp may be described as a torch burning alcohol which gives an almost invisible flame under ordinary conditions. If, however, air containing Freon is fed into the base of the lamp and the flame permitted to impinge upon a piece of metallic copper, it changes from colorless to a bright green. This test will disclose a concentration of Freon as low as 0.01 per cent.

Freon is noninflammable and nonexplosive, in fact its vapor has fire extinguishing properties. Freon is nontoxic and nonirritating. Test animals lived for weeks in an atmosphere containing 20 per cent. Freon by volume without experiencing any harmful physical effect, either immediate or delayed. Freon is not absorbed by foods or materials being refrigerated. It has no effect on flowers, fruits, vegetables, dairy products or furs.

T. K. C.

THE USE OF A THERMIONIC TETRODE FOR VOLTAGE CONTROL.

BY

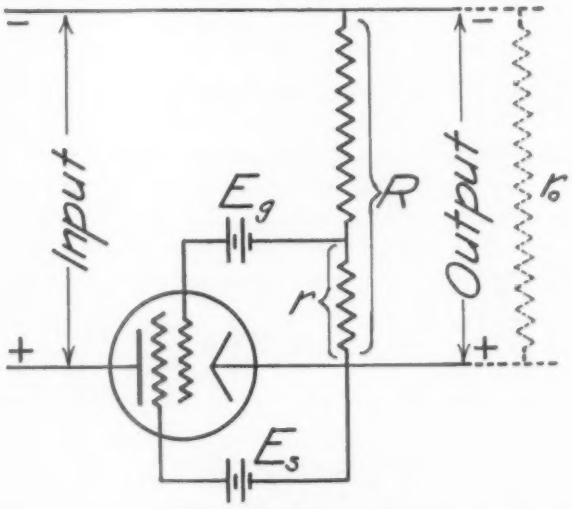
J. C. STREET AND THOMAS H. JOHNSON,

Bartol Research Foundation of the Franklin Institute.

BARTOL RESEARCH FOUNDATION.
Communication No. 68.

The circuits described here have been used to supply potentials of the order of 1,500 volts to a set of Geiger-Mueller counters. In this case the current consumption is only of the order of 10^{-8} amperes but the applied voltage must be constant to within two or three volts to insure a uniform counting rate. The rectified a.c. from a transformer operating from the lighting circuit and controlled by one of these circuits proved far more steady than a battery of storage cells of one ampere hour capacity even though the a.c. supply fluctuated several per cent. The circuits may have other applications where low currents at constant voltage are necessary and they have the

FIG. 1.



First type of voltage control.

advantage of requiring no expensive parts and are simple and easy to set up and operate.

The source of potential which has been used was a 2,000 volt transformer operating from the 110 volt lighting circuit and rectified by kenetrons. Any other source of potential, however, would have served as well. A diagram of the first control circuit is shown in Fig. 1. The resistances were of the wire wound type sold under the trade names of Akraohm or Precision and the four element heater type tube was a C24 or C24A, these having less variable characteristics than the filament type C22 tube. The 36 tube, however, would have served as well as the 24.

The most important characteristic of a circuit for voltage control is the variation of output potential E with input potential V. Since the current i in the plate circuit is a function only of the plate potential e_p and the control grid potential e_g (the screen grid potential E_s considered constant) we may write

$$\frac{di}{dV} = \frac{\partial i}{\partial e_p}\frac{de_p}{dV} + \frac{\partial i}{\partial e_g}\frac{de_g}{dV}, \tag{1}$$

where

$$e_p = V - iR \qquad \text{and} \qquad e_g = E_g - ir, \tag{2}$$

it being assumed that e_g is negative so that the grid current is zero. Hence,

$$\frac{de_p}{dV} = 1 - R\frac{di}{dV} \qquad \text{and} \qquad \frac{de_g}{dV} = -r\frac{di}{dV}. \tag{3}$$

Substituting these values in (1) and solving

$$\frac{di}{dV} = \frac{1}{r\mu + R + Z_p}, \tag{4}$$

where

$$Z_p \equiv 1/\left(\frac{\partial i}{\partial e_p}\right) \qquad \text{and} \qquad \mu \equiv Z_p\frac{\partial i}{\partial e_g} \tag{5}$$

and since $E = Ri$,

$$\frac{dE}{dV} = R\frac{di}{dV} = \frac{R}{r\mu + R + Z_p}. \tag{6}$$

In order that the tube shall have its normal characteristics the plate potential must be of the order of 100 or 200 volts. This condition is brought about by an adjustment of the grid potential through the choice of r in relation to E_g according to (2).

A numerical example of the circuit constants and operating characteristics is as follows.

$$R = 2.07 \times 10^6 \text{ ohms}, \qquad r = 70{,}000 \text{ ohms},$$
$$E_g = 45 \text{ volts}, \qquad i = .71 \text{ milliampere},$$
$$e_p = 160 \text{ volts}, \qquad E_s = 45 \text{ volts},$$
$$V = 1{,}620 \text{ volts},$$
$$e_g = -3 \text{ volts}.$$

Under these conditions the value of μ for an average C24 tube is about 700 and Z_p is about .5 megohm. The substitution of these numbers in (6) gives

$$\frac{dE}{dV} = \frac{1}{26} \text{ volts per volt.}$$

The important part of (6) is

$$\frac{dE}{dV} \doteqdot \frac{R}{r\mu} \doteqdot \frac{E}{E_g\mu}, \tag{7}$$

from which it is evident that better control results from a tube with a large μ value operating from a large grid bias potential. The value of 45 volts for E_g was chosen because of the convenience of a commercial B battery unit.

Measurements of the variation of output potential in a circuit having the above constants showed a linear variation over a range of $\pm$ 50 volts on the input with the ratio

$$\frac{\Delta E}{\Delta V} = \frac{1}{25} \text{ volts per volt}$$

in close agreement with the calculated value. The most convenient fine adjustment of the output potential was obtained by varying r, but the range of this variation was limited by the condition that the plate potential must stay within the normal operating range between 80 and 220 volts. Wider variations were obtained by varying the input voltage.

The influence of other possible variations must also be examined. The most important of these is the variation of the grid bias potential E_g. The plate current is again a function only of e_p and e_g where these quantities are given by (2). The variation of plate current with grid bias potential E_g may therefore be written

$$\frac{di}{dE_g} = \frac{\partial i}{\partial e_g}\frac{de_g}{dE_g} + \frac{\partial i}{\partial e_p}\frac{de_p}{de_g}. \tag{8}$$

From (2)

$$\frac{de_g}{dE_g} = 1 - r\frac{di}{dE_g} \quad \text{and} \quad \frac{de_p}{dE_g} = -R\frac{di}{dE_g}. \tag{9}$$

Hence

$$\frac{di}{dE_g} = \frac{\mu}{\mu r + R + Z_p} \doteqdot \frac{1}{r}. \tag{10}$$

Therefore $dE/dE_g = R/r$, which in the example considered above has the value 30 volts per volt. This is about the ratio of E to E_g and hence the percentage fluctuation due to this cause is about the same as the percentage fluctuation of E_g itself. In this connection it may be pointed out that no current flows in the battery E_g so that fluctuations in its potential would be expected to be small.

We next consider variations produced by possible changes in the screen grid battery E_s. The plate current is now a function of E_s, e_g, and e_p where e_g and e_p are given by (2). Therefore

$$\frac{di}{dE_s} = \frac{\partial i}{\partial E_s} + \frac{\partial i}{\partial e_g}\frac{de_g}{dE_s} + \frac{\partial i}{\partial e_p}\frac{de_p}{dE_s} \tag{11}$$

from (2)

$$\frac{de_g}{dE_s} = -r\frac{di}{dE_s} \quad \text{and} \quad de_p/dE_s = -Rdi/dE_s; \tag{12}$$

therefore

$$\frac{dE}{dE_s} = R\frac{di}{dE_s} = \frac{R\mu_s}{r\mu + R + Z_p} \doteqdot \frac{R\mu_s}{r\mu} \doteqdot 1, \tag{13}$$

where

$$\mu_s = Z_p\frac{\partial i}{\partial E_s}.$$

It is seen, therefore, that the variations due to this cause are only one thirtieth those due to the variation of E_g.

The next question of interest is the effect of the load current in the output circuit. In the above discussion this current has been assumed to be zero. We may consider the output load to be represented by a resistance r_0 and taking this into account equations (2) become

$$e_p = V - i_1 R, \qquad e_g = E - i_1 r,$$

where i_1 is the current through R and is related to the plate current i by

$$i_1 = i\, r_0/(R + r_0).$$

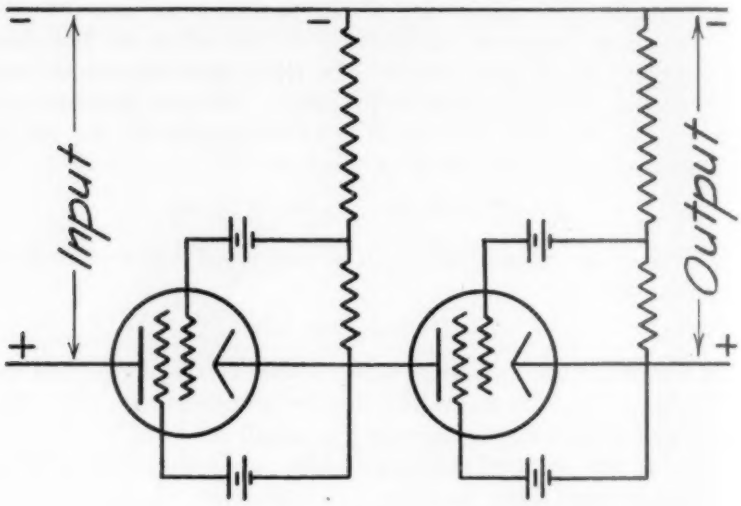
This modification introduces the factor $r_0/(R + r_0)$ into the first and second terms of the denominators of (4), (6), (10), and (13). Its effect, however, is small as long as $R \ll r_0$. If $R = r_0$, the control represented by (4) is only half as good as that in the limit $r_0 = \infty$. A variation of the load resistance will likewise introduce a variation in the output potential but this will be small if $R \ll r_0$. In the first approximation this variation is

$$\frac{dE}{dr_0} = \frac{RE}{r_0^2} \text{ volts per ohm.}$$

If it is necessary to obtain a more constant potential supply than that given by the simple arrangement just described it seems quite feasible to extend the method to two or more stages as shown in Fig. 2. With two stages there would be an additional decrease of fluctuation by a factor of approximately $R/2\mu r$ which would reduce the variations for the numerical case already cited more than tenfold, that is to about one tenth of a volt in 1,500. Further stages might also be added and the only final limitation to the ultimate steadiness would be fluctuations in the tubes and grid batteries.

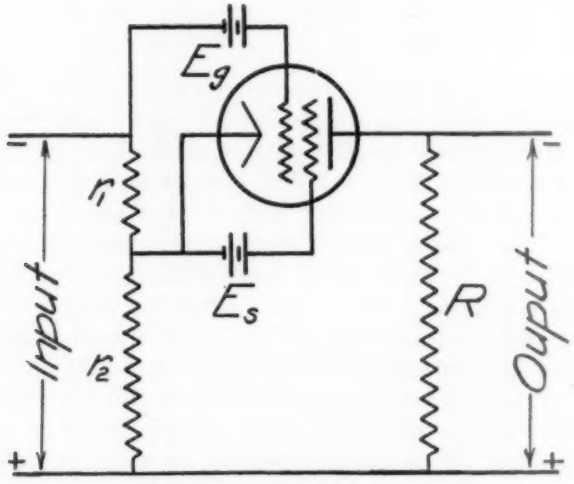
An alternative arrangement of the circuit has been found even more satisfactory, for some purposes, than that described above. This arrangement is shown schematically in Fig. 3. The voltage supply from the kenetrons was connected across the two resistances r_1 and r_2 in series. The potential drop across r_2 was the supply voltage for the plate

FIG. 2.



First type of circuit extended to two stages.

FIG. 3.



Second type of voltage control.

circuit and that across r_1 determined the grid potential. The output was taken across the resistance R in the plate circuit so that, as in the previous case, the desired condition for constant output potential was the maintenance of constant plate current.

It is evident that the opposing effects of the potentials across r_1 and r_2 will tend to reduce variations in the plate current i which are caused by changes in input voltage. A simple analysis is the clearest illustration of the action of the circuit. With symbols defined as before

$$e_p = V - Ri - r_1\left\{ i + \frac{V - r_1 i}{r_1 + r_2} \right\}$$

and

$$e_g = -\,r_1\left(\frac{V - r_1 i}{r_1 + r_2}\right).$$

Differentiating these and substituting in (1) it is found that

$$di/dV = \left\{ \frac{1}{Z_p}\left(1 - \frac{r_1}{r_1 + r_2}\right) - \frac{\partial i}{\partial e_g}\left(\frac{r_1}{r_1 + r_2}\right) \right\} \Bigg/ \left\{ 1 + \frac{R}{Z_p} - \frac{r_1^2}{(r_1 + r_2)Z_p} + r_2\frac{\partial i}{\partial e_g} - \frac{r_1^2}{r_1 + r_2}\frac{\partial i}{\partial e_g} \right\}.$$

This variation actually vanishes if

$$\mu = r_2/r_1. \qquad (15)$$

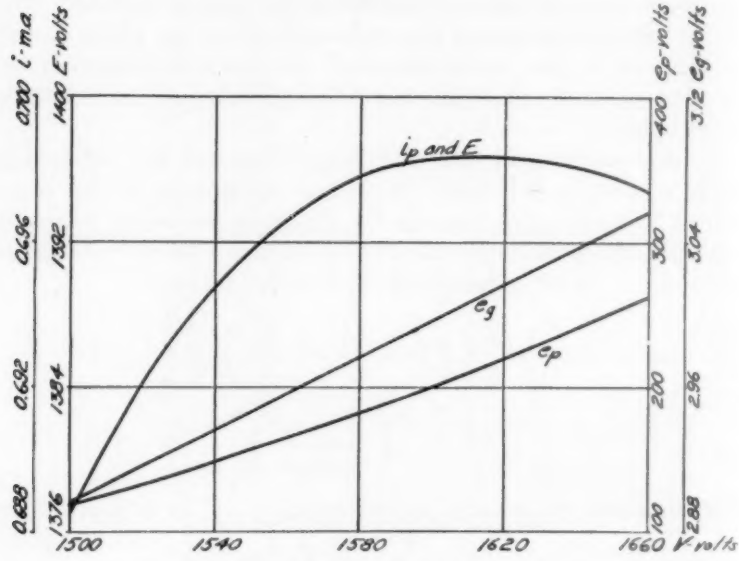
In the case of a tetrode, μ varies appreciably with the potentials applied to the plate and grid and hence one might not expect that the ratio r_2/r_1 as determined for one set of conditions would prevent a change in i over a wide range of variation of V.

The following numerical example is to be compared with the circuit first described. With a 24A tube and with circuit constants as follows:

$r_1 = 2{,}000$ ohms, $R = 2 \times 10^6$ ohms, $E_g = 0$,
$r_2 = 2 \times 10^6$ ohms, $E_s = 45$ volts,

a variation of V between 1,500 and 1,650 volts gave the values plotted in Fig. 4 for i, E, e_p and e_g. For a variation in V of 60 volts between 1,580 and 1,640, E varied by less than

FIG. 4.



Characteristics of the second type of circuit.

one volt and the regulation was therefore considerably better than the factor of 25 obtained with the first circuit. With greater variation in V this advantage was no longer evidenced as can be seen from the curve.

In choosing one of these circuits for voltage control, convenience and flexibility are important considerations. Each of the circuits has certain advantages. The first circuit is more flexible in that the output potential is easily adjustable in small steps whereas the second can be adjusted to require no control grid bias battery so that fluctuations due to this source may be eliminated.

POLYCHROME PHOTOGRAPHY.

BY

FREDERIC E. IVES,

Cresson Medalist, The Franklin Institute.

A greatly simplified process for making color photographs suitable for the album or framing.

I am showing results by a process which is such a radical departure from the established scientific mode of procedure that when I have described the process without showing the results I have been suspected of being afflicted with senile dementia; but when I have shown the results without explaining how they were produced, it has been assumed that they were superior examples by the most approved scientific methods.

For nearly half a century we have had methods of trichromatic photography capable of producing beautiful results, but such of the methods as produced prints suitable for the album or framing, which is what the layman has always demanded, have never been popularized for the amateur because their successful operation involved the perfect coordination of a large number of factors made variable by unavoidable variations in the materials used. They have been suitable for operation only by trained experts.

Three negatives have been required, and three superposed color printings. Elaborate and expensive special cameras have been devised to make the three negatives at one exposure from a single point of view, and the production and registration of the color prints have demanded exceptional manipulative skill.

In this process, only two negatives are made, on two plates or films in face contact, in an ordinary plate camera. There are also only two prints, one on paper and one on transparent film, which when cemented together produce the results which I am showing.

The method is reminiscent of Columbus' feat of standing an egg on end. It is actually a three color process, although

only two negatives and two prints are made, and the differentiation of colors is perfectly automatic, but at the same time under control.

Naturally, something is sacrificed to obtain the results by such simple means, though no one has suspected this from an examination of the prints. Every color that can be reproduced by a three negative and three print process is produced by this process, with the exception of cobalt blues, which reproduce as blacks, bluish pink, which reproduces as salmon pink, and some purples which reproduce as dull reds. These colors are comparatively rare and seldom of pictorial importance, and can if desired be produced with great facility by local treatment on the face of the top print, which is a tenuous dyed gelatine relief on a thin celluloid film.

The "you press the button, we do the rest" plan has developed such headway in this country that amateurs will often prefer to make only their own negatives, entrusting the color print making to people especially equipped for such work, but still permitting them to make such local alterations as their fancy dictates, before finally applying a thin protective coating of benzole-mastic varnish by means of a pledget of absorbent cotton.

In short, this is eminently a picture making process, to be judged on its merits as such. The process is a truly scientific compromise, effected by making the "red" print a "dichroic red"—pure red in the deep shadows, shading down to orange and yellow in the palest shades, and thus combining with the cyan blue of the paper print to produce greens where they belong, and red, orange and yellow fruits and flowers where they belong. The separate prints look most unpromising, but their combination effects a seemingly magical transformation. The process is in no sense an accidental discovery. It was carefully reasoned out, and I venture to think that it is an invention of considerable practical importance.

The prints shown were made in the kitchen of my living apartment, with "gaslight" printing. Enlargements to any desired size can be made with a copying camera. Snap-shot negatives can be made in direct sunlight.

The process as it stands involves the application of several inventions first disclosed in Ives patents most of which have now expired. Only ill health prevented me from perfecting it long ago, and further refinements of procedure and standardization are still possible. Of course I should have had the use of a proper laboratory, and been able to employ assistants.

Still Smaller Movie Films.—From the Eastman Kodak Company through the medium of *Science Service* comes the announcement that four pictures now can be taken upon the film space of an ordinary amateur 16 millimeter movie frame. Finer grained photographic emulsion developed for recording sharp images of distant stars has made this possible. This quadrupling of the number of images on a foot of film is accomplished by running a 16 millimeter film through a special type of camera twice. The camera takes twenty-five feet of film and is sufficiently small to fit into the coat pocket. The first time through one-half of the width of the film is exposed. Then the film is changed from one reel to the other and the other half is exposed. Each picture taken is only half the depth of an ordinary 16 millimeter film image. Twenty-five feet of the new film will therefore contain as many pictures as a hundred feet of the conventional amateur movie film and will run four minutes. When the film is processed it is split down the center and the two pieces spliced end to end. High optical and mechanical precision is necessary in the eight millimeter movie apparatus. The fast anastigmat lens of the camera is the size of a small pea but is made of three pieces of glass each separately ground on each side with extreme accuracy.

T. K. C.

Sound Proofing Broadcast Studio.—A Philadelphia broadcasting company describes innovations in the soundproofing of their new broadcasting studios. Each room will have a "live" and a "dead end." One-half to two-thirds will be lined with sound absorbing material to form a "dead end" where the microphones will be placed. Another stunt is to furnish the larger studios with zigzag walls so as to prevent any reverberation of sound occurring between parallel wall surfaces.

Such a studio is actually a room within a room. Its special constructed walls, floor and ceiling are suspended in position by supports which are non-conductors of audible vibrations. The acoustical treatment in all studios will include a one and one-half inch rock wool blanket placed against the soundproof wall and another blanket of the same size and style placed in front of it with a two-inch air pocket between the two blankets. The outer blanket is covered with perforated metal. Each studio and control room window will be composed of a triple sash and three panels of glass measuring $\frac{1}{4}''$, $\frac{5}{8}''$ and $\frac{3}{8}''$ respectively. The heaviest glass, the $\frac{5}{8}''$ is placed between the lighter as an added guard against sound waves caused by any vibration between the panels.

T. K. C.

RESOURCES OF THE OCEAN.*

BY

HARDEN F. TAYLOR,

President, The Atlantic Coast Fisheries Company.

INTRODUCTION.

The ocean basin, being the lowest portion of the surface of the earth, is a catch-basin into which, throughout the ages, chemical substances of every kind have been dumped by the many moving forces of nature. Loose and transportable materials are moved, either directly and swiftly or indirectly and by degrees, downward to the ocean; particles are carried bodily by wind, water-course and glacier; other substances are dissolved in water and transported to the ocean where they are caught as in a trap and held permanently. The ocean has become a reservoir of accumulated wealth of chemical materials that makes the resources of the land appear insignificant by comparison. This accumulation of useful materials is a direct challenge to daring chemists to find ways and means of winning them back from the sea. It seems safe to predict that coming generations will realize the inexhaustible hoard of wealth in the sea, the complete assortment of chemicals, three-fourths of the living creatures of the earth of the greatest diversity of form and composition, and also perhaps power and refrigeration.

DIMENSIONS AND MAGNITUDES OF THE OCEAN.

It will be helpful first to fix in mind the grosser magnitudes of the ocean.

The surface area of the earth is 196,950,277 square miles.[1] Of this area 139,295,000 square miles, or 70.73 per cent., are occupied by ocean. The average depth of the ocean is estimated to be 2.38 miles, while the greatest depth yet found

* Presented at the Stated Meeting held Wednesday, February 17, 1932.

[1] Lambert, W. D., "The Figure of the Earth and the International Ellipsoid of Reference," *Science*, **71**, 1926, p. 242–248. (Area of ellipsoid: 510,100,934 km².)

FIG. 1.

Showing deeps of the ocean. From Murray and Hjort, "Depths of the Ocean." By permission of The Macmillan Company, publishers.

is 5,900 fathoms (10,800 meters, or 6.7 miles) in the Philippine Trench near Mindanao. Since the pressure is about 1 atmosphere for each 10 meters depth, the bottom pressure at this point is about 108 atmospheres or nearly 16,000 pounds per square inch. The compressibility of sea water is such that if the pressure on the whole ocean were relieved the sea level would rise by about 32 meters or 104 feet.

The approximate areas of the ocean covered of different depths are:

TABLE I.

Fathoms (1 fathom 6 ft.).	Square English Miles.	Percentage of Total.
0–1000, 0–1.1 mi.	21,725,000	15.59
1000–2000, 1.1–2.2 mi.	26,915,000	19.34
2000–3000, 2.2–3.3 mi.	81,381,000	58.42
3000–4000, 3.3–4.4 mi.	9,058,000	6.50
over 4000, over 4.4 mi.	216,000	0.15

From Murray and Hjort, "Depths of the Ocean"—Macmillan & Co.

More than four-fifths of the ocean floor is covered by water more than a mile deep, and two-thirds is covered by more than 2000 fathoms or 2 1/5 miles of water. The volume of the ocean is 331,000,000 cubic miles, and the total mass is about 1.57×10^{18} tons.

Sea water is "water" only in the sense that water is the dominant compound. It is a most complex liquid, containing about 3.5 per cent of dissolved inorganic compounds, much organic substance, suspended particles of solid, together with a host of living things, many of which are microscopic and contribute no small part to the properties of sea water. We do not know what was the composition of the first primitive seas. But we do know that throughout the ages, many forces have been bringing material to the ocean, from outer space, from the interior of the earth and from the land. Meteors, or cosmic dusts, arriving on the earth have seven chances out of ten of falling in the ocean. Numerous rock meteors, as well as those of iron and nickel, are found strewn on the bottom of the sea. Volcanoes have contributed much to the ocean, either directly or by dust thrown high into the atmosphere, to be carried by wind over the ocean and brought down by rain. Submarine fissures, fumaroles and springs bring materials from the interior of the earth. Glaciers rasp out rocks, mud, and debris and when they arrive at the shore,

yield icebergs to drift to sea where they melt and drop their cargoes of minerals. This effect was undoubtedly greater during the ice ages in former times than it is now.

Perhaps the greatest and most continuous addition to the ocean is carried by water. It is estimated that about .82 meter depth of water evaporates on the average over the whole ocean per annum. This is about 71,389 cubic miles, or 3.24×10^{14} tons, of water. This vapor, which is pure water with no mineral, rises in the air, is blown about the earth by wind and is precipitated as rain. If we assume that 29.27 per cent. of it falls on land, then 20,900 cubic miles, or 9.5×10^{13} tons, of rain falls on the land each year, or 22 inches depth of rainfall over all the land of the earth. This water erodes and washes away the soil which is carried as mud and silt down the brooks, creeks and rivers back to the ocean. Part of it seeps into the ground to some depth, dissolving out soluble materials, issuing again in springs, geysers and artesian wells and returning with its dissolved and suspended substance to the sea, when it evaporates again, leaving its load of chemicals in the ocean, only to return to the land for more. The more soluble substances go soonest and most completely. Whatever increases solubility increases the impoverishment of the land and enrichment of the sea. Among the most soluble compounds are the nitrates, the halogen compounds, i.e., the chlorides, iodides, bromides, of the alkali and alkaline earth metals, sodium, potassium, rubidium, calcium, magnesium, etc. The less soluble substances, such as silica, or sand, and the clays, or alumina, are left behind. These less soluble materials are now the bulk of our soil.

Various agencies assist the process of escape of minerals to the sea. Every stroke of lightning oxidizes some atmospheric nitrogen to nitric acid, which is carried down by the rains to the soil where it dissolves some minerals as nitrates. Some of this is used by plants and some of it is dissolved and washed away to the sea. A very recent estimate, by Dr. W. J. Humphreys of the U. S. Weather Bureau, of the amount of atmospheric fixation of nitrogen is 770 million tons yearly, or 12 pounds per acre annually. Nitrogen from the air, fixed by nodules on the roots of certain plants, also doubtless plays a

similar rôle in robbing the soil. The carbon dioxide of the atmosphere dissolves in rain water and increases the solubility of limestone, large quantities of which are transported down the rivers to the sea. While the above substances are carried in vast quantities to the sea, all minerals are soluble to some extent, though some of them more slowly. Silica or sand, and alumina, phosphates, and the like, are carried in small amounts, but amounting, over geologic time, to huge quantities. Silica occurs dissolved in sufficient quantity in sea water to supply material for the shells of diatoms, radiolaria and the supporting frames of some sponges.

The agencies of erosion by wind, frost, exposure to changes of temperature and sunlight, all tend to aid the escape of substance from the land to the sea. Mountains and hills slowly crumble, valleys are chiseled out, the rocks disintegrate and decompose and are dissolved and washed away. Man himself has been a party to the robbery of the land. The primitive forest with its leaves, roots and vines, held the soil in place, and served to restrain the flow of water to some extent and to prevent direct erosion of the soil. Now that man has cleared away the forest and laid bare the ground, soil substance is carried away much more rapidly than ever before. In more primitive days man returned sewage, wastes, and dejecta to the soil; now he has become sanitary and discharges what came from the soil into the rivers and eventually into the ocean. Man is also digging iron, tin, copper, zinc and other minerals from the ground, making them into automobiles, tin cans, buildings; eventually these are worn out, discarded, piled up in junk heaps, there to rust, corrode, burn, dissolve and wash away finally to the sea. Vast quantities of materials are destroyed by combustion as fuel or for disposal of wastes. All of the coal, most of the petroleum and much of the products of forests are eventually consumed by fire. Their smoke and dusts go into the air and their ashes are leached out by rain, the portable materials going to the sea.

It is estimated that the annual "net operating income" of the ocean, derived from the rivers, is 2 billion, 735 million metric tons, and that the whole ocean contains 4.6×10^{16} tons of dissolved material in its 331 million cubic miles.

TABLE II.

Dissolved Mineral Reserves and Annual Income of the Ocean.[2]

Element or Radical.	Reserve in Ocean Millions of Metric Tons (000,000 omitted).	Annual Income from Rivers Millions of Metric Tons (000,000 omitted).
Carbonate, CO_3	95,600,000	961.3
Sulphate, SO_4	3,553,000,000	332.0
Chlorine, Cl	25,538,000,000	155.3
Bromine, Br	86,800,000	—
Nitrate, NO_3	275,000	24.6
Sodium, Na	14,130,000,000	258.3
Potassium, K	510,000,000	58.0
Calcium, Ca	552,800,000	557.7
Magnesium, Mg	1,721,000,000	93.3
Iron, Alumina, etc., R_2O_3	—	75.2
Silica, SiO_2	—	319.2
Phosphates, as P	75,000	—
Total	46,187,550,000	2,834.9

Of the total number of 92 chemical elements, 48 are known, some of them tentatively, to occur in the sea—in solution in the water, in the tissues of living marine plants or animals, or in the bottom sedments.

TABLE III.

The Chemical Elements.

Present in the Ocean.		Not Yet Reported in the Ocean.	
Aluminum	Magnesium	Actinium	Platinum
Argon	Manganese	Antimony	Polonium
Arsenic	Molybdenum	Beryllium	Praseodymium
Barium	Neon	Bismuth	Protoactinium
Boron	Nickel	Cerium	Radon
Bromine	Nitrogen	Dysprosium	Rhenium
Cadmium	Oxygen	Erbium	Rhodium
Caesium	Phosphorus	Europium	Ruthenium
Calcium	Potassium	Gadolinium	Samarium
Carbon	Radium (?)	Gallium	Scandium
Chlorine	Rubidium	Germanium	Selenium
Chromium	Silicon	Hafnium	Tantalum
Cobalt	Silver	Holmium	Tellurium
Columbium	Sodium	Illinium	Terbium
Copper	Strontium	Indium	Thorium
Fluorine	Sulphur	Iridium	Thulium
Gold	Thallium	Lanthanum	Tungsten
Helium	Tin	Lutecium	Uranium
Hydrogen	Titanium	Masurium	Ytterbium
Iodine	Vanadium	Mercury	Yttrium
Iron	Xenon	Niton	Zirconium
Krypton	Zinc	Osmium	
Lead	No. 85	Palladium	
Lithium	No. 87		

[2] Mostly from F. W. Clarke, Data of Geochemistry, U. S. Geological Survey, Bulletin 616. Third Edition, 1916. Extensive bibliography.

This list merely represents the state of our knowledge at the present time. It can scarcely be doubted that such common elements as antimony, bismuth, beryllium, mercury, selenium, tellurium and tungsten occur in the ocean. We may venture even so far as to say that, in the very nature of the case, all the elements must occur in the sea in some quantity. The analytical difficulty of separating exceedingly small quantities of rare elements in the presence of all the others is a great obstacle to determination of these hitherto undetermined elements in the sea. It is significant, however, that both elements Nos. 85[3] and 87[4] have been found in the sea. These are instances of great precision of analytical method, which if generally applied, would doubtless reveal all the other elements.

It will again assist us to comprehend the magnitude of the ocean if we reckon how much of even the rarest elements is in the whole ocean. One milligram, the size of a pinhead, of an element per metric ton of water is one part per billion. Yet this small quantity amounts to 4.56 ordinary short tons per cubic mile of water. Since the whole ocean is 331,000,000 cubic miles, it would contain 150 billion tons of an element that occurs to the extent of only one part per billion in water. While chemists on land wrangle and dispute over the possible identification of a faint line in the spectrum of a mineral showing that a rare element is suspected to be present in infinitestimal traces, the ocean contains millions or billions of tons of it, sufficient for mountains.

SEA WATER.

The materials upon entering the ocean from the rivers begin at once to take part in a vast milling of chemical changes. Reacting, dissolving, precipitating, redissolving, being taken up by living plants and animals, going through the life cycle and set free again. The ocean is forever stirred by wind, tide and current, horizontal and vertical, exposed to change of temperature, frozen and thawed, exposed to light of various

[3] Fred Allison, E. J. Murphy, E. R. Bishop and A. L. Sommer, *Phys. Rev.*, 37, p. 1178–1180, 1931.

[4] Fred Allison, E. R. Bishop, A. L. Sommer and J. H. Christensen, *Jour. Am. Chem. Soc.*, **54**, p. 613–615, 1932.

intensities and colors, so that almost every kind of reaction has a chance to occur. The composition of the ocean as it now exists is the result of millions of years of these reactions. It contains about 3.5 per cent. of dissolved inorganic salts, among which preponderate, of course, the more soluble and the more abundant elements of the earth. Since we cannot well comprehend the whole ocean, one cubic mile may be taken as a sample. This cubic mile contains, among other things:

TABLE IV.

The More Abundant Elements and Compounds in One Cubic Mile of Sea Water.

Sodium chloride *	128,284,403	tons
Magnesium chloride	17,946,522	"
Magnesium sulphate	7,816,053	"
Calcium sulphate	5,934,747	"
Potassium sulphate	4,068,255	"
Calcium carbonate	579,832	"
Magnesium bromide	358,270	"
Rubidium	64,316	"
Fluorine	1,400	"
Barium	916	"
Zinc	450	"
Iodine	a minimum of 90	"
Arsenic	46 to 368	"
Phosphorus	up to 400	"
Nitrogen, combined	up to 1,300	"

* The compounds are, of course, hypothetical combinations of the elements and radicals actually found.

These figures are accurate down to, and including, rubidium. The more abundant compounds occur in remarkably constant proportion throughout the ocean. The less abundant elements appear to be more variable, perhaps, because of unsatisfactory analytical methods, but also because they actually vary. In the neighborhood of beds of sea weeds and sponges, iodine is much more abundant than it is on the high seas, and wherever vegetation is abundant fixed nitrogen and phosphorus are rapidly used up, under favorable conditions of light and temperature.

Of the less abundant elements, some have been definitely found in the water—aluminum, silicon, iron, copper, boron, cæsium, gold, silver, zinc, manganese and lithium, in small quantities.

Fluorine occurs in sea water to the extent of about 300 mg. per cubic meter, and is also found in the shells of molluscs and

in the tissues of all fishes which have been examined for it. Barium is found in quantities less than 200 mg. per cubic meter, and also occurs as particles of barium sulphate in the soft tissues of certain rhizopods. Iodides are among the most soluble compounds, and for this reason most of the world's supply of iodine is in the ocean, probably in large part in organic combination; the smallest amount reported is 20 mg. per cubic meter, and a maximum of 2800 mg. It occurs in all living things in the sea so far investigated. Arsenic varies between 20 and 80 mg. per cubic meter. It is found in the tissues of many organisms, such as lobsters and oysters, and in some marine plants it is suspected to play the part that is played in most plants by phosphorus.

Silver and gold, our old friends of stock promotion schemes, actually do occur regularly in sea water. The literature of the subject is highly confusing, reporting, as it does, amounts of gold varying from .01 mg. per cu. meter in surface and inshore water to 267 mg. in the deeps of the ocean. In the new 14th edition of the Encyclopedia Britannica, in volume 10, page 480, we find from 5 to 267 parts of gold in 100 million of water, or 50 to 2760 mg. per cubic meter, while on page 482, of the same volume, the amount is 2 to 60 mg. The largest amount given is richer than many commercial ores. A concentration of 267 mg. per liter, or 1200 tons per cubic mile, at $542,000 per ton, would be worth over $664 million. Silver is also reported in varying large amounts, running around 10 mg. per cu. meter. Haber,[5] at the Kaiser Wilhelm Institute, has redetermined gold and silver from many localities and depths, with distinctly disappointing results. He reports amounts in a few hundredths of a milligram in sea water to as much as 4.8 mg. in melted polar ice, and silver from .01 to 8.9 mg., the latter in 2,000 meters depth of the Atlantic, and 20 mg. in polar ice. Haber says that looking for a dependable richness of precious metals in sea water in an endurable climate is like looking for a needle in a haystack. He found decidedly more gold in the living organisms than he did in the water itself.

Sea water is radioactive in an amount equivalent to 1.2 to 17×10^{-6} mg. radium per cu. meter, or 5 to 70 gm. per cubic

[5] F. Haber, *Zeit. f. angew. Chemie*, 40 Jahrg, p. 303–314, 1927.

mile. If radium is really the source of this radioactivity, the amounts indicated would be worth from $250,000 to $3,500,000.

Numerous other elements, not yet reported from sea water directly, have been found in the bodies of living plants and animals in the sea.

For example, vanadium has not been reported in sea water directly, but has been found in the amount of .123 per cent. of the dry substance, along with iron, copper and manganese, in the body tissues of a holothurian in Gulf Stream water off Tortugas, Fla., by Phillips [6] and in an ascidian from the Bay of Naples by Henze.[7] Lead and zinc were also found in conchs far from shore off Florida by Phillips.[8] A small organism, a radiolarian, *Podocanelius*, floating in the waters of the high seas was found by Bütschli to be almost pure strontium sulphate, while Vogel [9] found strontium in shells of molluscs and corals. A recent paper by Newell and McCollum [10] reporting on spectrographic examination of fish meals, or dried fish residues used for animal feeding, showed a remarkable array of elements in the common food fishes.

Cobalt occurs in lobsters and mussels, and cadmium in the shellfish *Pecten maximus*. Nickel is found in molluscs to the extent of 2 mg. per kg. of dry weight.

The ordinary fertilizing elements, nitrate and phosphate are present in minimal quantities at the surface of the sea where they are used up, under the influence of sunlight, by marine plants, but they tend to accumulate in the deep, comparatively stagnant, abysses of the deep ocean. It has been estimated [11] that the deep ocean basin contains 275,000 million tons of nitrate nitrogen and 75,000 million tons of phosphate phosphorus. Living activity and growth at sea

[6] A. H. Phillips, *Am. Jour. Sci.*, **46**, p. 473–475, 1918.

[7] M. Henze, *Zeit. Physiol. Chem.*, Bd. LXXII, p. 494–501, 1911; Bd. LXXIX, p. 223; Bd. LXXXVI, p. 340–344, 1913.

[8] A. H. Phillips, Carnegie Institution of Washington, Pub. No. 251, p. 89–93, 1917.

[9] O. Vogel, *Zeit. anorg. Chem.*, Bd. V, p. 42–55. Supplement, p. 55–62, 1894.

[10] J. M. Newell and E. V. McCollum. U. S. Bureau of Fisheries, Investigational Report No. 5, 8 p. Bibliography, 1931.

[11] H. W. Harvey, "Biological Chemistry and Physics of Sea Water," New York, 1928, p. 170.

TABLE V.—*Appearance of the principal lines of the elements in the spectrograms of the various fish meals.** (From Newell and McCollum.)

Type of meal	Aluminum	Barium	Boron	Calcium	Chromium	Copper	Fluorine	Iron	Lead	Lithium	Magnesium	Manganese	Nickel	Niobium	Phosphorus	Potassium	Silicon	Silver	Sodium	Strontium	Tin	Titanium	Vanadium	Zinc
Crab	4	3	...	5	3	4	4	4	3	5	5	3	4	...	4	4	3	3	5	5	...	3	3	3
Shrimp	3	1	...	5	3	4	...	4	2	4	5	3	...	...	4	4	3	...	5	5	...	3	3	3
Flame-dried sardine (California pilchard)	3	3	...	5	3	5	5	4	2	5	5	3	1	1	4	4	4	...	5	4	...	...	...	3
Steam-dried sardine (California pilchard)	3	3	...	5	3	5	5	4	3	4	5	3	...	...	4	5	4	3	5	4	...	2	2	3
Indirect-flame-dried sardine (California pilchard)	3	3	...	5	3	5	5	4	3	5	5	4	...	...	4	4	2	...	5	4	...	...	...	3
Direct-flame-dried sardine (California pilchard)	3	3	...	5	3	5	5	4	3	5	5	4	...	...	4	4	2	2	5	5	...	3	2	3
Mackerel	3	2	...	5	3	5	5	4	3	4	5	3	2	...	4	4	3	3	5	5	...	3	3	3
Tuna	2	3	...	5	3	5	5	4	3	4	5	3	...	...	4	4	3	2	5	5	...	3	2	3
Flame-dried menhaden	5	5	...	5	4	5	5	4	2	5	5	5	2	2	4	4	4	3	5	5	...	3	...	3
Steam-dried menhaden	5	5	...	5	4	5	5	4	2	5	5	5	...	2	4	4	4	3	5	5	...	1	3	3
Maine herring	2	...	...	5	3	5	...	4	4	3	5	3	...	...	4	4	3	...	5	4	1	...	...	...
Steam-dried Alaska herring	2	...	...	5	3	5	...	4	3	2	5	3	...	...	4	5	...	...	5	4	...	3	1	...
Flame-dried Alaska herring	2	...	...	5	3	5	5	4	2	3	5	3	...	2	4	5	...	...	5	5	...	...	...	...
Indirect-flame-dried herring	2	...	...	5	3	5	4	4	3	3	5	4	2	...	4	4	2	...	5	5	...	3	3	3
Steam-dried salmon	4	4	...	5	3	5	5	4	3	4	5	4	2	...	4	4	2	4	5	5	3	2	...	3
Flame-dried salmon	3	4	...	5	1	5	5	4	2	4	5	4	...	2	4	4	2	...	5	5	...	...	3	3
Vacuum-dried white-fish meal †	3	2	...	5	4	5	4	4	3	4	5	4	...	...	4	4	3	...	5	5	2	...	2	3
Flame-dried white-fish meal †	3	2	...	5	3	5	4	4	3	4	5	4	3	...	4	4	3	3	5	5	2	3	3	3
Kelp	3	2	5	5	1	5	...	4	3	3	5	3	2	...	3	5	3	2	5	5	...	3	3	3

* Elements searched for in this work: Li, Na, K, Rb, Cs. Cu, Ag, Au, Be, Mg, Ca, Sr, Ba, Zn, Cd, Hg, B, Sc, Yt, La, Al, In, Tl, C, Si, Ge, Sn, Pb, Ti, Zr, P, As, Sb, Bi, V, Nb, Ta, Cr, Mn, Fe, Co, Ni, Mo, Ru, Rh, Pd, W, Os, Ir, Pt.

† The term "white-fish meal" as mentioned in the above table describes a meal light in color made from the waste of such ground fish as cod, haddock, pollock, etc., as a by-product of our North Atlantic fisheries.

KEY

Completely invisible by lens	0	Visible to the naked eye as a light line	3
Questionably visible by lens	1	Visible to the naked eye as a heavy line	4
Visible by the aid of the lens	2	Sufficiently heavy to cause a fogged line	5

seems to be determined by the rate at which these nutrients are brought to the surface. Wherever bottom configuration and currents bring rich bottom water to the surface, there life is abundant, as on our fishing banks of the North Atlantic. These organisms, in the greatest diversity of form and function, take from the water reservoir of chemicals the things they need, die, disintegrate, and return them to the water, or are eaten by larger animals which thereby accumulate their needed elements. Tiny shells and skeltons of dead organisms begin their long journey sinking downward, redissolving as they go. In the deepest ocean most of the lime redissolves, while most of the iron and alumina may be deposited on the bottom. The solubility of compounds in sea water may not be at all the same as it is in fresh water. For example, it has been shown that calcium phosphate is much more soluble in the presence of magnesium compounds than in their absence.[12]

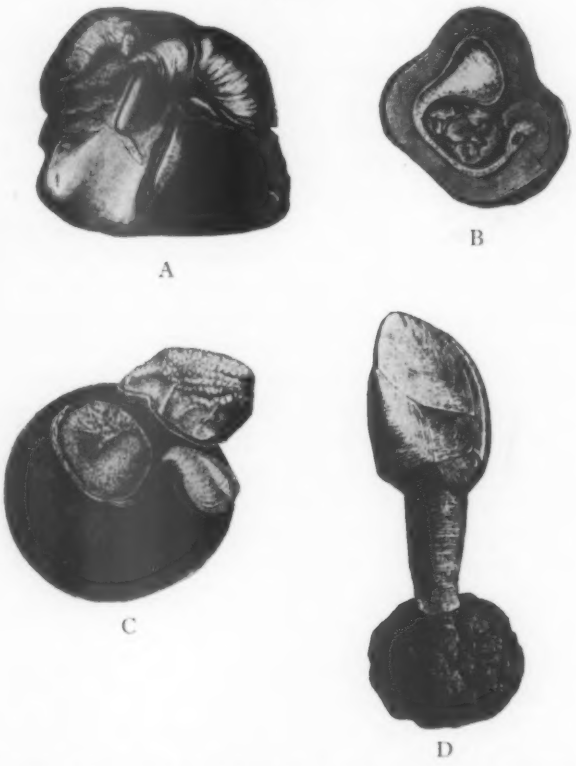
THE OCEAN BOTTOM.

The bottom of the sea is the most perfect example on earth of finality. A vast undulating plain, dark as night, cold, lifeless, finished. When elements reach the bottom of the sea they are mostly oxidized, energyless, immovable. The bottom plain consists of sedimentary remains of tiny organisms of silica, iron, and calcium mixed with sediments and precipitated insoluble matters, pumice stone, and volcanic dust, which, in the course of time, are compressed to dense rock. The floor of the ocean is strewn with meteorites, glacial rocks, fossilized bones and teeth of ancient animals, and old shells. As these shells, teeth, and bones lie for centuries they become slowly encrusted with deposits of manganese oxide, iron, and a most surprising assortment of elements, some of which have never been reported from either sea water or from living things in the water. These nodules or lumps are of two principal kinds, manganese and phosphatic. Manganese-iron oxides occur widely in marine deposits as minute grains which act as coloring matter in nearly all deep sea clays. In certain abyssal regions they form concretions around fossils, fragments of rock or coral, and may look like

[12] B. Kramer and P. G. Shipley, *Science*, **66**, p. 484–485, 1927. J. C. Forbes, *Jour. Biol. Chem.*, **93**, p. 255–268, 1931.

marbles, potatoes or cricket balls. The indications are that these elements are derived from volcanic matter. Beads of magnetic iron, of meteoric origin, often alloyed with cobalt and nickel, have been separated from bottom deposits by means of a magnet. Spherules of glauconite, an amorphous

FIG. 2.



Manganese nodules. A. Tympanic bone of whale encrusted with manganic concretion. B. Cross section of a manganese nodule, accumulated around a tympanic bone. C. Manganese nodule, low forms of animal life attached. D. Manganese nodule with barnacle attached. From Murray and Hjort, "Depths of the Ocean." By permission of The Macmillan Company, publishers.

silicate of iron and potassium, are abundant in sediments of land origin, appearing as casts of shells of small organisms, the shells themselves having dissolved away after the casts were molded inside. Small round nodules have been trawled from about 675 fathoms, off Colombo, containing 75 per cent.

barium sulphate. The little that we know of the tiny shelled foraminifera indicates some interesting chemistry of composition. Whatever they contain has been carried to the bottom where they form millions of square miles of area.

TABLE VI.

Analysis of Manganese Nodule.

	Soluble in Hydrochloric Acid.	Insoluble Portion.
	per cent.	per cent.
Silica, SiO_2	—	74.58
Titanium, TiO_2	—	.72
Alumina, Al_2O_3	6.34	12.93
Iron, Fe_2O_3	26.97	4.79
Magnesia, MgO	4.60	—
Lime, CaO	4.02	1.45
Barium, BaO	—	.67
Strontia, S_2O	—	.11
Manganese, MnO	42.94	—
Nickel, NiO	1.96	—
Cobalt, CoO	.56	—
Zinc, ZnO	.20	—
Copper, CuO	.74	—
Lead, PbO	.10	—
Thallium, Tl_2O	.06	—
Soda, Na_2O	—	3.62
Potash, K_2O	—	.95
Phosphorus, P_2O_5	.22	.11
Molybdenum, MoO_3	.20	—
Vanadium, V_2O_5	.14	—
Sulphur, SO_3	.94	—
Carbon dioxide, CO_2	.58	—
Peroxide oxygen	9.42	—
	99.99	99.93

The phosphatic concretions contain from 20 to 24 per cent. P_2O_5 together with other commoner compounds. It is certain that the bottom of the sea is no less significant than the water as a depositary for chemical substances. Indeed, it is now a record from which may be read a large part of the history of the world. The water is primarily the store of solubles, the bottom the store of insolubles, both being almost immeasurable in extent. We have seen from the composition of the nodule that nickel, molybdenum, titanium, thallium, strontium, barium, lead, cobalt, vanadium, and zinc occur on the bottom. Joly found deep sea deposits to be much richer in radium than the average terrestrial rocks, being richest

far at sea, and where calcium deposits are least abundant, especially in the red clays and radiolarian oozes.

We have seen that the tendency of earth forces is to move chemical materials to the sea. Reverse processes are negligible that might return some of these things to the land and restore them to usefulness. Storms at sea whip up spray, some of which finds its way into the higher atmosphere where the water evaporates, leaving flecks of sea salts. These are carried over land mostly near the sea-coast and brought down by rain, but they are promptly washed back again. If man needs the ocean's wealth, he must go to the ocean and get it.

Can we exploit the chemical wealth of the ocean? Of course, we are already producing salt, iodine, bromine, and magnesium chloride and hydroxide from sea water—things which can be separated by such crude processes as evaporation and precipitation. If we are to remove those substances that are present in more attenuated dilution, recourse must be had to more refined methods, such as those of physical chemistry. The writer has experimentally added traces of gold salts to water in sufficient amount to give a color with benzidine acetate, and removed it by adsorption with kaolin, or purified clay, beyond the limit of detection with the reagent. The kaolin is merely stirred into the water and allowed to settle, carrying the gold down with it. Perhaps most of the gold that has got into sea water has been adsorbed by the clay mud brought in by the rivers, and carried to the bottom, where it would still repose. It is well known that alumina jelly also adsorbs the heavy metals and removes them from water.

Fats must play a significant rôle in ocean chemistry. They are produced in great quantities by diatoms, and many fishes have much fat, while whales and porpoises have extraordinary amounts of fat in their bodies. Disintegration of these plants and animals releases fat directly into the ocean. Petroleum is believed to have originated from fats in large bodies of water. But how can fat, being of low specific gravity, get to the bottom? Of course, some of it might be carried down with diatom shells and the carcasses of animals, but what becomes of the fat that must escape directly into the water which, if it were not removed, would by this time

have made the ocean into a rich chowder? The ocean must contain enzymes derived from the dejecta of animals. Fat splitting enzyme would decompose fats into free fatty acid and glycerin; under the alkaline conditions of the water, the fatty acids would form alkali-metal soaps which, in turn, would react with all the heavy metals to form heavy and insoluble soaps. Thus not only can fats find their way to the bottom, but may be the means of carrying the heavy metals along with them. Soaps might be an artificial means of separating the more valuable from the less valuable elements.

The organic matter can also be separated from sea water by simple physical means. A sample of sea water was whipped into a foam, the water drawn from under the foam and whipped again and separated repeatedly until it would no longer foam. The foam was then dried and found to be organic matter containing some fat.

Since living organisms are able to extract such things as iodine, copper, vanadium and manganese from the water, a study of their chemistry might suggest methods. Proteins, such as gelatin, readily combine with metallic ions if they are more alkaline than their isoelectric points. Perhaps organisms use this principle.

The deep waters of most of the ocean are very cold, approaching the freezing point of fresh water. Not very far from the Atlantic coast, millions of cubic miles of this cooling brine exist, sufficient to cool and condition the air in all the homes, public buildings and subway tubes in the world, and would never be missed. The efforts of Georges Claude to realize power from the temperature differences between surface and bottom of the ocean are based, of course, on perfectly sound principles. In this instance, as in that of refrigeration, the hindrance is one, not of principle, but of availability at the places where the benefits are needed. The prospects are not bright for their immediate utilization, but with our growing superfluity of labor, widening scope of engineering knowledge and facilities, and of technical skill, such giant projects as these may be undertaken some time in the future.

It does not seem too fantastic to suggest that the possibilities of direct exploitation of marine wealth should be under serious and systematic study somewhere. Nobody is doing

it now. We do not even have a catalogue of what is in the sea water at our doors, not anything more than merely suggestive data about concentrated elements in living things. Such research could hardly be expected to pay for itself, perhaps for many years, but the possibility is always before us that it might be rewarded a thousandfold. If we are permitted to conceive the possibility of exploiting sea water, and the sea bottom, the very magnitude of the supply, so far as all elemental material is concerned, is so great that we could dismiss forever all fear of exhaustion of raw materials.

BIOLOGICAL SIGNIFICANCE OF SEA WATER.

If sea water is significant as a potential source of inorganic constituents, it is even more significant as a biological fluid. Indeed, it possesses so many of the characteristics of the fluids that are found in living things that it may itself be regarded, in a sense, as a living fluid. It contains, as we have seen, all of the inorganic nutrients in approximately the proportions to which living things are adapted.

Sea water also contains a huge amount of organic matter. Living animals contribute to the water their excrements and secretions containing enzymes, ferments and a great number of other products of physiological activity. Bacteria secrete a variety of enzymes directly into the water. Dead plants and animals disintegrate and their body substances diffuse into the water and become mixed and scattered. These substances are proteins in colloidal solution, a number of amino-acids and, of course, a great variety of fats. Future research remains to be done on the determination of the nature and abundance of the several organic constituents of sea water. Many researches point to an organic content of about 10 mg. per liter,[13] equivalent to 45,600 tons per cubic mile. Sea water is slightly alkaline, the alkalinity varying only within very narrow limits. It contains, of course, a great diversity of living things ranging from the smallest bacteria to giant whales.

If the sea contains the bulk of the earth's materials for life, it also receives seventy-one per cent. of all the radiant

[13] August Krogh, Conseil Permanent International pour l'Exploration de la Mer, *Rapports et Procès-Verbaux des Réunions*, **75**, 1931, p. 7–34. Copenhagen. Extensive bibliography.

energy which arrives from the sun. On land, all organic material or food substance is manufactured, under the influence of radiant energy from the sun, by plants, and all animals whatsoever must subsist directly or indirectly on food manufactured by plants. So it is at sea. Sunlight energy is absorbed at and near the surface of the sea, and under its influence primary manufacture of living substance from inorganic materials is carried out by tiny plants, microscopic

FIG. 3.

Chain colonies of diatoms. Silicious capsules seen here edgewise formed into chains. × 150.*

or near-microscopic in size, floating in the water—mostly in the top fifty meters—which take the silicon, calcium, phosphorus, and strontium to make their shells and skeletons, and carbon dioxide and water to produce starches, sugars, fats, and the many complex chemicals that are characteristic of plants. As these simple carbohydrates and fats, containing only carbon, hydrogen and oxygen, are built up into more elaborate compounds, the other elements needed are always

* Figures 3, 4, 6, 7, 8 and 10, courtesy Dr. Henry B. Bigelow, and U. S. Bureau of Fisheries.

found at hand in the water—nitrogen, sulphur, phosphorus, iron, iodine, manganese, and all the others.

These tiny plants are among the most fascinatingly beautiful forms of nature. Diatoms, with tiny capsules of silica, containing much fat, are of almost inconceivable variety and numbers. About 15,000 species of them have been described and millions of square miles in the Antarctic are covered with their shells. Peridinians, brown and blue-green algæ, luminous species, and living shelled plants abound, all of curious and

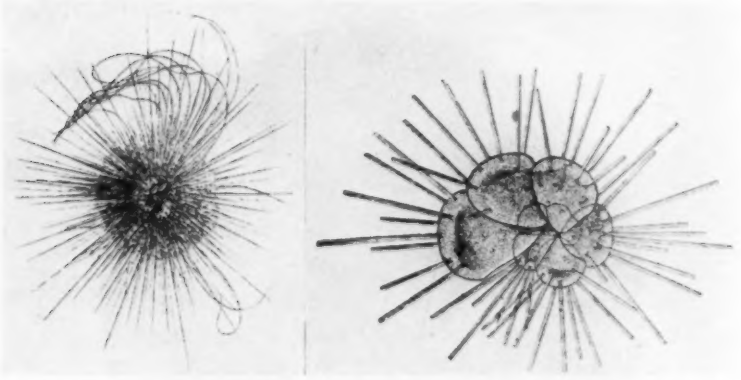
FIG. 4.

Peridinian plankton. Tiny plants which, with diatoms and algae, constitute the primary manufacturers of food in the ocean. × 25.

beautiful symmetry. Collectively, this tiny life is called plankton, which term includes both the small animal and vegetable life of the sea. On the great fishing banks of the North Atlantic, after the winter winds, currents, and temperature changes have brought to the surface the deep abyssal water, rich in nitrogen and phosphorus, and when the lengthening days of spring increase the amount of sunshine, the vernal burst of plankton growth fills the water with so much microscopic life that although the individual cells are almost

transparent, the water becomes literally muddy with it. The productivity of plants at the surface of the sea has been determined in only a few instances. In the English Channel it was estimated [14] that 4,000 tons of vegetable matter is produced annually per square mile. Another estimate on the Norwegian coast indicates a production equivalent to 7.3 tons of glucose per square mile of surface per day.[15]

FIG. 5.



Tiny forms of animal plankton. A × 10. B × 50. From Murray and Hjort, "Depths of the Ocean." By permission of the Macmillan Company, publishers.

The round of life in the sea is magnificent in its vastness, diversity and complexity. The tiny plants are consumed by somewhat larger plankton animals, up to, say, 1/4 inch in size. These animal forms are as diverse as those of plants, tiny snail-like molluscs, or pteropods, shrimp-like crustacea, the copepods, beautiful globigerina and radiolarians, with limy and silicious skeletons or shells, and jelly fishes. Mixed plankton of tiny plants, animals, fish eggs, larvæ, and spores of all sorts of organisms, is strained out of the water by the gills of some kinds of fishes which live near the surface and are adapted to subsist on planktonic food. Their gills are made up specially as a sieve like a fine-tooth comb. The fish pumps water

[14] W. R. G. Atkins, Conseil Permanent International pour l'Exploration de la Mer, *Journal du Conseil*, 1, No. 3, p. 197–226, 1926. Copenhagen.

[15] For further details and bibliography, see Harvey, op. cit., p. 10–11, 32–35.

through this sieve and strains out the plankton. The plankton is swallowed as food. In recent investigation of the herring in the North Sea [16] it was estimated that three hundred tons of plankton would be required to provide one "average" meal for the herring that were landed at the east coast fishing ports in England in 1926, or, at one "average" meal per day, 109,500 tons per year. This estimate says nothing about the

FIG. 6.

Calanus finmarchicus, slightly magnified. These tiny animals subsist on diatoms, peridinians, etc., and, in turn, are staple food of herring and many other fishes.

herring landed in Scotland, Norway, Holland, and other ports, nor of that amount consumed by other kinds of fishes, nor of the vaster amount not caught at all. The herring family, consisting of herring, menhaden, shad, sardines, etc., as well as mackerel, are consumers of plankton and are an important link in the ocean as converters of tiny life into the form of fish available to larger fish which cannot use plankton directly. These plankton converters are in turn eaten by larger fishes, such as bluefish, weakfish, and many others.

[16] R. E. Savage, "Great Britain: Fishery Investigations," Ministry of Agriculture and Fisheries, Series 2, 12, No. 3, 1931. London.

If it were possible to exterminate the herring family, hundreds of other and larger fishes would die of starvation amid plenty of plankton food that they are unable to eat.

Within the plankton population the struggle for survival goes on fiercely, with venomous stings, clawings, parasitic infestations, depredations by bacteria, and destruction by excessive change in temperature. The casualties result in a settling to the bottom of a "planktonic rain" of tiny

FIG. 7.

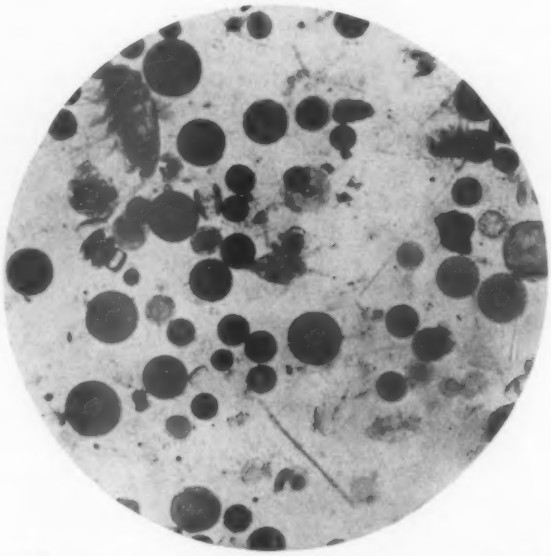
Mixed plankton of tiny animals, which subsist on diatoms and peridinians, and themselves are the food for fishes. × 3½.

organisms that are dead or *hors de combat*. This "rain" on arriving at bottom becomes part of the mud which is devoured in great quantities by worms, mussels, scallops, conchs, and other bottom dwellers which thus derive their livelihood from the plankton life at the surface. These bottom mud eaters, in turn, become food of crabs, lobsters, cod, and haddock, and so, whether at surface or at bottom, the chain of life leads, via consumer and consumed, to larger and larger creatures until they attain a size available to man. The tiny

shells and skeletons of these little organisms finally come to rest and accumulate at the bottom.

The vitamins of cod liver oil which are not made, but only accumulated, by the cod, have been traced to their ultimate source in the oil of diatoms. These little plants grow and make oil in the sunshine at the surface of the sea. Oil obtained from a pure culture grown from one single specimen of diatom, *Nitzschia closterium*, was found to be similar to cod

FIG. 8.



General mixture of plankton, plant and animal, showing fish eggs, copepods, and, in the background, tiny diatoms and other microscopic plants. This is the food of many fishes. × 40.

liver oil in chemical and nutritional characteristics, as also in odor.[17] We know relatively little of the chemistry of plankton but enough to be certain that the planktonic flora and fauna of the sea are gatherers and concentrators of many of the rarer chemical elements. We saw above that a plankton-organism *Podocanelius* regularly makes its beautiful skeleton of strontia; that seaweeds and sponges contain iodine far in excess of that in sea water; that Haber found more gold in the

[17] A. B. Ahmed, *Biochem. Jour.*, **24**, p. 860–865, 1930.

FIG. 9.

Gills of the menhaden showing fine comb structure, or gill rakers, for collecting plankton out of the water for food.

plankton than in the water; that certain sea-anemones, sea cucumbers and sea aquirts (holothurians and ascidians), which are all plankton eaters, contain remarkable quantities of vanadium; that oysters, which are plankton eaters have copper, arsenic, manganese, iron, and numerous other elements in their bodies, which are in all probability, derived from plank-

FIG. 10.

Highly magnified section of gill rakers from menhaden gills, showing fine teeth on the rake themselves, which act as a sieve to strain out animal and vegetable plankton from the water.

ton organisms. We have seen that the cod and haddock have such a diversity of elements as aluminum, barium, columbium, chromium, copper, fluorine, lead, lithium, manganese, silver and numerous others. These fishes eat shellfish and worms which, in turn, derive their sustenance from planktonic rain which subsides to the bottom as sediment.

We now see why the ocean is a perfect nutrient solution; it contains all the elements that are necessary for the maintenance of every form of life; it is almost uniform in composition throughout its vast extent, because it is stirred by wind, tide and current. In it something like three-fourths of all living things exist.[18] In a sense, the ocean may be regarded as the normal abode of life where everything is suited to that end, while on land life is a special adaptation, a sort of afterthought of nature, to maintain life, even though conditions are much less perfect. As we now examine the questions as to what elements are necessary to maintain human life, we shall see that on land many things are scarce or missing, and that, at almost any spot, some element or other is inadequate.

The Ocean and the Nutrition of Man and Animals.

In view of the chain of food manufacture in the ocean, from diatoms to fishes, we are now prepared to expect sea foods to contain not only the commoner elements associated with life, but an assortment of the rarer elements that are only now being investigated seriously by biochemists.

What elements are normal and necessary in our food? A few years ago, we were taught that the body consisted of 12 elements,—oxygen, carbon, hydrogen, nitrogen, calcium, phosphorus, potassium, sulphur, chlorine, sodium, magnesium, and iron. A few others had been detected in traces, but no significance was attributed to them—fluorine in enamel of the teeth, copper in liver and bile, iodine in the thyroid. It was supposed that these traces were accidental contaminants of food and water and were merely en route through our bodies.

Table VII summarizes our present knowledge of the approximate composition of the human body.[19]

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[18] W. K. Brooks, *Journal of Geology*, **2**, p. 455, 1894.

[19] Karl Klinke, "Der Mineralstoffwechsel, Physiologie und Pathologie," Leipzig und Wien, 1931, p. 42. Extensive bibliography.

TABLE VII.

Composition of the Human Body.

	Per Cent.	Cumulative Total Per Cent.		Per Cent.	Cumulative Total Per Cent.
Oxygen	62.43	62.340	Sodium	.08	99.940
Carbon	21.15	83.580	Magnesium	.027	99.967
Hydrogen	9.86	93.440	Iodine	.014	99.981
Nitrogen	3.10	96.540	Fluorine	.009	99.990
Calcium	1.90	98.440	Iron	.005	99.995
Phosphorus	.95	99.390	Bromine	.002	99.997
Potassium	.23	99.620	Aluminum	.001	99.998
Sulphur	.16	99.780	Silicon	.001	99.999
Chlorine	.08	99.860	Manganese	.001	100.000

These elements add up to 100 per cent., but obviously the estimates are not absolutely correct. We know that many other elements are found in the human body, in small but undetermined traces.

TABLE VIII.

Elements that Have Been Reported to Occur in Traces in the Human Body.

Arsenic	Copper	Silver
Boron	Lead	Strontium
Cæsium	Lithium	Tin
Chromium	Nickel	Titanium
Cobalt	Rubidium	Zinc

It will be noticed that the elements up to and including iron in Table VII, make up 99.995 per cent. of the human body, and that the total remainder of about .005 per cent. consists of trifling amounts of 19 other elements. This field is now one of active research, in which some of the most significant discoveries have only recently been made.

Among the rarer elements in the body, iodine was first to be proved essential. This element forms highly soluble compounds, and most of it is in the ocean. Wide spaces of land are practically destitute of it. It has been estimated [20] that it would take about 2000 years for a person to drink enough Lake Superior water to accumulate an amount equal to that

[20] J. F. McClendon and J. C. Hathaway, *Proc. Soc. Exp. Biol. and Med.*, 21, p. 129, 1923. For bibliography, see D. K. Tressler and A. W. Wells, appendix 1 to Rept. U. S. Commissioner of Fisheries (Doc. 967) for 1914, p. 1–12, 1924. Also, Klinke, op. cit.

found in the thyroid of a normal adult. Iodine deficiency diseases are widespread. Every drop of sea water contains iodine, and all sea animals and plants so far examined for it contain it, sponges and seaweeds being extraordinarily rich in it.

Copper has recently taken on a new and vital significance. Certain types of anemia are characterized by scarcity of red blood corpuscles and of hemoglobin. Although iron is often clearly deficient, administration of iron does not cure or prevent anemia. In 1926 and 1927,[21] it was shown that a diet rich in liver has a marked beneficial effect on pernicious anemia. Later, it was found that liver extract was effective, the eating of liver became widespread, liver quickly came into great demand and the price of liver soared. Liver extract was made by pharmaceutical houses and was widely used. A significant chemical characteristic of liver is its marked content of copper, which is much higher in fetuses and young animals than in adults. In 1928,[22] it was found that copper has a stimulating effect on hemoglobin formation. From 1929 to 1931, it was found that liver, liver extract, liver ash or the copper equivalent alone of the liver ash are all equally effective in preventing or curing anemia provided, of course, that iron is present in the diet. Iron alone, while needed for blood regeneration, will not be assimilated in the absence of traces of copper.[23]

Copper seems to play a rôle in the assimilation of iron analogous to that of vitamin D in the assimilation of calcium. Copper is of widespread biological significance. In the blood of most molluscs and of crustaceans, lobsters, crabs, shrimps, etc., a copper compound, hemocyanin, plays the rôle in blood that iron does in human blood. It has been shown that failure

[21] G. R. Minot and W. P. Murphy, *Jour. Am. Med. Assoc.*, **87**, 470–476, 1926; ibid., **89**, p. 759–766, 1927.

[22] Whipple, Robscheit-Robbins, Elden and Sperry, *Proc. Soc. Exp. Biol. and Med.*, **25**, p. 478, 1928. Also E. B. Hart, H. Steenbock, J. Waddell and C. A. Elvehjem, *Jour. Biol. Chem.*, Vol. 77, p. 297–812, 1928.

[23] Waddell, Steenbock, Hart, and associates, *Jour. Biol. Chem.*, **83**, p. 243–250; 252–260; **84**, p. 115–130; p. 131–141, 1929. See also G. T. Lewis, T. E. Weichselbaum and J. L. McGhee, *Proc. Soc. Exp. Biol. and Med.*, **27**, p. 329–331, 1930; F. A. Underhill, J. M. Orten and R. C. Lewis, *Jour. Biol. Chem.*, **91**, p. 13–25, 1931.

of tiny oyster larvæ to set, or attach themselves to the bottom and grow, is caused by lack of copper; that when traces of copper are added to the water the tiny oysters become attached and grow normally.[24] This finding appears to be valuable in the solution of one of the greatest problems of oyster growers, namely, getting a good "set." Copper is always present in sea water, and apparently is of universal occurrence in marine animals and plants, and now takes its place as an element of vital biological importance.

Manganese has also been found to be important. Results obtained in 1931 [25] show that female rats that are deprived of manganese fail to suckle and rear their young, while male rats become sterile by degeneration of the reproductive organs. In one shellfish, *Pinna*, it functions in the blood in the same way as copper in oysters and iron in man. As a soil fertilizer for plants, manganese has been shown to be beneficial, especially when the soil is alkaline. Manganese is present in sea water and in marine plants and animals, and is apparently a universal and necessary component of living protoplasm.

Fluorine has been known for many years to occur in the hard enamel of our teeth, and in traces in bones. Experimental administration of fluorine always seemed to be harmful to animals and man. In 1925, at the Iowa Agricultural Experiment Station, comparison [26] was made between rats fed on a diet free from fluorine and others on diets in which fluorine was present in smaller traces than had been tested before. It was found that if fluorine was present, it had the remarkable effect of causing certain of the upper teeth to grow unusually long—so long, in fact, that they began to perforate the cheeks. Amounts of sodium fluoride of 0.1 or more per cent. of the diet were decidedly harmful. Some people have hard and enduring teeth—others soft teeth which decay in early life. That fluorine in the diet has something to do with this differ-

[24] H. F. Prytherch, *Science*, **73**, p. 429–431, 1931.

[25] E. R. Orent and E. V. McCollum, *Jour. Biol. Chem.*, **92**, p. 651–678, 1931. J. S. McHargue, *Am. Jour. Physiol.*, **77**, p. 245–255, 1926. A. R. Kemmerer, C. A. Elvehjem and E. B. Hart, *Jour. Biol. Chem.*, **92**, p. 623–630, 1931. See also, for general bibliography, M. B. Richards, *Biochem. Jour.*, **24**, p. 1573, 1930.

[26] J. A. Schulz and A. R. Lamb, *Science*, **61**, p. 93–94, 1925.

ence seems entirely possible, as indicated by the above experiments, and also by its unvarying presence in the enamel of teeth. Too much fluorine, however is objectionable in causing spotty enamel of the teeth. Sea water contains a substantial amount of fluorine, and so far as analyses go, sea foods contain it. Certainly haddock and cod contain a sufficiency.

Cobalt and nickel have been found associated with insulin in the pancreas,[27] and in traces in other organs. Bertrand at the Pasteur Institute has found the effects of insulin to be promoted if accompanied by cobalt and nickel in traces.

The present state of knowledge of the numerous other elements in the body permits nothing more than speculation about their significance. Exposed, as we are under modern industrial conditions, to a great variety of chemical substances, it is to be expected that almost all the commoner chemical elements find their way, in spectroscopic traces, into our bodies, and that they are by way of being eliminated or are put out of the way in some tissues of the body. Tin may arrive in canned foods, copper from water pipes, aluminum from cooking utensils, zinc from galvanized containers, and all sorts of things as dust in the air that we breathe. Yet, the accumulations in certain tissues always suggest physiological function, as iron in the red corpuscles, iodine in the thyroid, copper in the liver, and fluorine in the enamel of the teeth, and arsenic in the hair and nails. Zinc is most abundant in the genitalia and brain, lithium and titanium in the lungs. In at least some cases the glands preside over the physiology of special elements—iodine in the thyroid, copper and iron in the liver, magnesium in the adrenals, calcium in the parathyroids. Barium is found in the retina in the eyes of the ox.

Research in this most interesting field will eventually tell us what elements are significant and useful and what are accidentally present. We know that deficiencies of certain elements are widespread. The processes of nature that have caused the accumulation of elements in the ocean have depleted the land. Many of the materials that are needed for life have been washed out of the land and carried to sea. Our fertilizer industry, crude as it now is, is based on known defi-

[27] G. Bertrand, *Science*, **64**, p. 629–630, 1926. P. Dutoit and C. Zbinden, Compt. rend., T. 190, p. 172–173, 1930.

ciencies of such elements as nitrogen, phosphorus and potassium. Other elements are beginning to be recognized as deficient in soils, and may be supplied as fertilizers, for example, manganese, boron, and titanium. The widespread deficiency of iodine is now generally recognized, public health measures are being taken to supply it, and copper is now being sought in foods as an agent in the treatment of anemia.

In the sea, there is and can be no deficiency. Every element necessary for life is present everywhere and the living animals and plants of the ocean select what they require. Wherever an element exists in a marine animal or plant in greater concentration than it is in sea water, we may logically suspect physiological significance. Sea foods are capable of supplying all the elements that are necessary in our foods, whether we know what they are or not. In sea foods, the necessary elements have not only been selected and assimilated on the basis of the natural requirements of living tissue, but they are stored and available in the form of a natural food in something approaching the proper proportions for the diet of man.

What is said of the ability of fish to supply the rarer elements in human diet, applies with equal force to the feeding of farm animals, whose dietary requirements are essentially the same. As the fish industry was conducted in the past, the portions of fish, such as head, skins, and bones, which were not eaten by people, were, nevertheless, shipped to consumers and wasted. The modern fish industry ships only the edible portions, retains the offal which is dried, ground, and marketed as fish meal for use as a protein supplement in the ration of poultry, pigs and dairy cattle. Many tests at agricultural experiment stations indicate its superiority over proteins derived from land sources, apparently because of its content of the rarer elements.

The world consumption of sea foods is estimated at about 30,000,000,000 pounds.

The utilization of sea products as food, relatively small as it is, is of the nature of a reversal of the process of enrichment of the sea by a return of the constituents of the sea to the land.

THE RED SHIFT.

BY

H. E. BUC.

Within the last few years considerable attention has been given to a phenomenon which is felt to be of cosmic significance. Spectra arriving from distant parts of the universe show a marked shift towards the red. A literal interpretation on the basis of Doppler's principle would ascribe enormous recessive velocities to the source of the light. What is particularly puzzling is that the apparent speed of the source depends on its distance from us. Not only are the nebulæ running away from us at terrific speeds but the farther they are from us the faster are they fleeing from us. Once again, the earth is the center of the universe, not its headquarters this time, but its principal plague-spot. Such naïve geocentrism could hardly be entertained. In the light of the theory of relativity, however, this is not quite as implausible as it sounds. With respect to fundamental phenomena every observer, anywhere, is at the center of things, in the same sense that every observer manages to be at the center of his own horizon. If the red shift, then, really signifies some motion, this motion must be a fundamental phenomenon connected with the very structure and order of the physical universe. This conviction has led to a most amazing speculation implying the explosively rapid destruction of the universe. In our present ignorance we can hardly judge the plausibility of this idea; but admittedly, it is under the strain of a major difficulty. It leads to an age for stars far shorter than had been calculated hitherto on apparently good grounds by more than one method. In this communication, a simple explanation will be advanced, which will dispense with any motion whatever on the part of the source of the light. Furthermore, it will involve only a slight extension of ideas now widely accepted.

Even before the theory of relativity, which identifies mass with energy, Jeans proposed the hypothesis that stellar

radiation is due to the destruction of matter. For our present purpose we will use only the basic idea—that larger units are continuously being frittered away into smaller units, and we will apply this idea to the energy units of radiation. In other words, an isolated quantum slowly but steadily dissipates part of its mass. This at once explains the red shift. The further the origin of the light the longer has the quantum been on its way, the more of its mass has it lost and the longer its wave-length on arrival.

The law of degradation is, naturally, that of a monomolecular reaction:

$$\frac{dx}{dt} = -kx,$$

with obvious meaning for the symbols. k is the proportional loss per unit time, its value of course depending on the unit taken. For convenience we will take the unit as one million years. Through the efforts of Hubble it is now possible to fix the approximate value of k. According to Hubble the Doppler interpretation would require a velocity of 465 kilometers per second per megaparsec. Reinterpreting in terms of proportional loss and time we obtain .00047 as the value of k. In other words, a quantum loses one part in two thousand every million years. A ray starting out as blue light would turn red in about 1400 million years.

It becomes of interest to compare this rate of degradation with the rate observed in the stars. As is well known, the luminosities of the stars vary enormously. In some stars the rate, ergs per gram, is far lower than the solar rate, which is two ergs per gram per second. In other stars the rate is much greater, reaching a maximum, as far as is known, of 11,000 to 15,000 ergs per gram per second in the case of Plaskett's and Pearce's stars. Leaving this topic for future discussion, the writer will, at this stage, do no more than point out that the highest known rates correspond to .00039 and .00053 as values for k—values practically identical with the one obtained for quanta on Hubble's estimate of nebular distances.

THE VIBRATIONS OF RODS AND PLATES.

BY

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A vibrating membrane with fixed edges has a certain relation to a wire with fixed ends; both are represented by a differential equation of the second order; the membrane having a two dimensional, the wire a one dimensional equation. This connection is shown by the following analysis.

In Fig. 1, the wire AB is parallel to the x axis and fixed

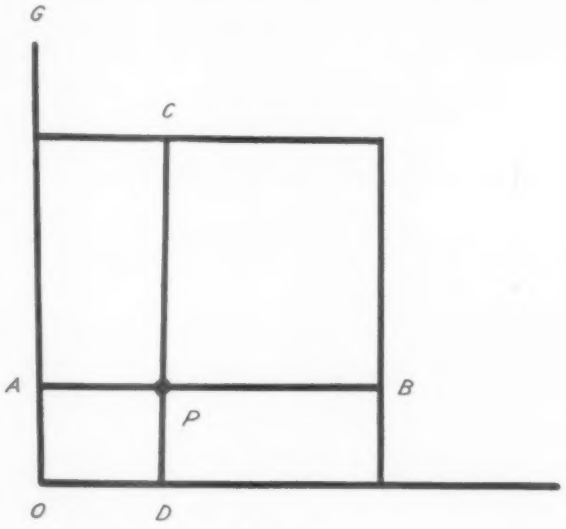


FIG. 1.

at both ends. If its displacement at any point x is denoted by w_x, the differential equation of motion will be

$$\frac{d^2w_x}{dt^2} = c^2\frac{d^2w_x}{dx^2} \qquad (1)$$

Similarly for CD a wire parallel to the y axis

$$\frac{d^2w_y}{dt^2} = c^2\frac{d^2w_y}{dy^2}. \tag{2}$$

If the wires are joined at P, this point is subject to the motions of both AB and CD: and as the wave amplitudes at P add up by scalar addition, it is permissible to write (1) and (2) together in the form:

$$\frac{d^2}{dt^2}(w_x + w_y) = c^2\left\{\frac{d^2(w_x + w_y)}{dx^2} + \frac{d(w_x + w_y)}{dx^2}\right\}. \tag{3}$$

Writing $w = (w_x + w_y)$, we have

$$\frac{d^2w}{dt^2} = c^2\left(\frac{d^2w}{dx^2} + \frac{d^2w}{dy^2}\right). \tag{4}$$

The solutions of all these differential equations (1), (2) and (4) are known. They are in order:

$$w_x = \sum_{m=1}^{m=\infty} \sin\frac{m\pi x}{a}\cos pt \tag{5}$$

$$w_y = \sum_{n=1}^{n=\infty} \sin\frac{n\pi y}{a}\cos pt \tag{6}$$

$$w = \sum_{m=1}^{m=\infty}\sum_{n=1}^{n=\infty} \sin\frac{m\pi x}{a}\sin\frac{n\pi y}{a}\cos pt, \tag{7}$$

in which a is the length of the wire and m and n are numbers to be determined from the boundary conditions. Now equation (4) is the differential equation of a membrane; and by comparing its solution (7) with solution (5) and (6), we see at once that it is possible, omitting the time factor, to obtain the mathematical equation of a membrane by multiplying together the solutions for two wires at right angles.

Following this analogy, it occurred to Ritz [1] to combine two rods with free ends in exactly the same way and thus obtain the solution for a Chladni plate with free edges. This solution is only approximate because the boundary conditions for the edges of a plate are not necessarily the same as for the

[1] Ritz, *Ann. der Phys.*, **29**, 1909, 751.

ends of a free rod. However, the nodal lines obtained by Ritz in his calculations agree with the experimental curves to within one or two per cent. When a rod is vibrating parallel to the x axis it is also necessary to consider the y coördinate because the rod in expanding along the x axis, is contracting along the y axis. The ratio of the contraction to the expansion is known as the dilatation constant. This feature of the vibrating rod is usually neglected in a calculation in one dimension and a slight error is introduced when the method is applied to two dimensions.

The one dimensional equation of a rod is known to be

$$\frac{d^4w}{dx^4} = k^4w \tag{8}$$

and in the complete form we have

$$\left(\frac{d^2}{dx^2} + \frac{d^2}{dy^2}\right)\left(\frac{d^2w_x}{dx^2}\right) = k^4w_x \tag{9}$$

$$\left(\frac{d^2}{dx^2} + \frac{d^2}{dy^2}\right)\left(\frac{d^2w_y}{dy^2}\right) = k^4w_y. \tag{10}$$

Since $w = w_x + w_y$, addition of (9) and (10) gives

$$\frac{d^4w}{dx^4} + 2\frac{d^4w}{dx^2dy^2} + \frac{d^4w}{dy^4} = k^4w. \tag{11}$$

Equation (11) which is the differential equation of two rods vibrating at right angles is of the same form as the differential equation for a vibrating plate, but the constant k for the rods is not the same as for the plate. However, the constants of the plate may be used in place of k. The approximate solution is obtained by multiplying together two solutions of equation (8) exactly as was done for the membrane. From (8) we find

$$w_x = A \sin k_m x + B \cos k_m x + C \sinh k_m x + D \cosh k_m x. \tag{12}$$

For a rod parallel to the y axis, w_y is obtained by writing y for x in equation (12).

The boundary conditions determine the values of k_m, A, B, C and D. These will be found in Rayleigh's treatise on

sound.[2] The final solution for the Chladni plate with free edges will then take the form:

$$w = \left\{ \begin{array}{l} (\cos k_m a - \cosh k_m a)(\cos k_m x + \cosh k_m x) \\ \quad + (\sin k_m a + \sinh k_m a)(\sin k_m x + \sinh k_m x) \end{array} \right\} \times \left\{ \begin{array}{l} (\cos k_n a - \cosh k_n a)(\cos k_n y + \cosh k_n y) \\ \quad + (\sin k_n a + \sinh k_n a)(\sin k_n y + \sinh k_n y) \end{array} \right\}, \quad (13)$$

in which k_m is found from the equation $\cos k_m a \cosh k_m a = 1$; so that for high values of $k_m a (k_m a > 5)$, $k_m a = m\pi - \pi/2$ where m is any integer. The value for k_n is derived in exactly the same way. The equations for the nodal lines are then found by adding a second term to (13) obtained from (13) by interchanging x and y and equating the sum to zero.

For large values of k_m equation (13) reduces to

$$w = A \cos \frac{m\pi x}{a} \cos \frac{n\pi y}{a}, \quad (14)$$

provided the points are not close to the edges, so that the approximate equation for the nodal lines in the interior of a vibrating plate with free edges is then

$$w = A \cos \frac{m\pi x}{a} \cos \frac{n\pi y}{a} + B \cos \frac{n\pi x}{a} \cos \frac{m\pi y}{a} = 0. \quad (15)$$

By choosing arbitrary values for m, n, A and B, it is possible to plot the nodal lines. Near the edges of the plate equation (13) must be used instead of (15). A complete discussion of equation (15) has been given by Ritz.[3]

In this article we shall use equation (15) with the understanding that, although it is only an approximation, the general theorems developed here are true for the more exact lines derived from equation (13) provided the proper corrections are made at the boundaries.

First when m and n are both even, the value of w is a maximum for $x = a/2$ or $y = a/2$. This means that two straight lines of maximum vibration cut one another at the center. They are also median lines parallel to the edges—hence, for even values of m and n, the plate is broken up into

[2] Rayleigh, *Sound*, Vol. I, p. 272, et seq.

[3] Ritz, *Ann. der Phys.*, **58**, 1909, 758.

FIG. 2.

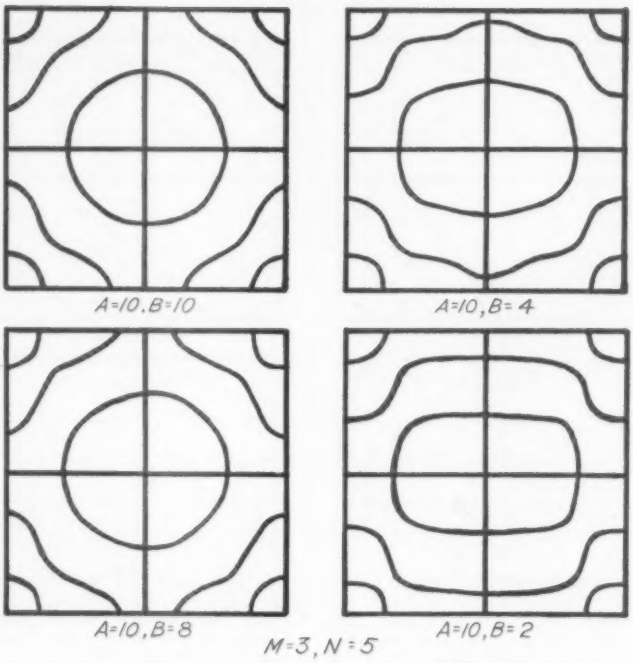

A=10, B=10
A=10, B=4
A=10, B=8
A=10, B=2
M=3, N=5
A=10, B=-2
A=10, B=-8
A=10, B=-4
A=10, B=-10
M=3, N=5

FIG. 3.

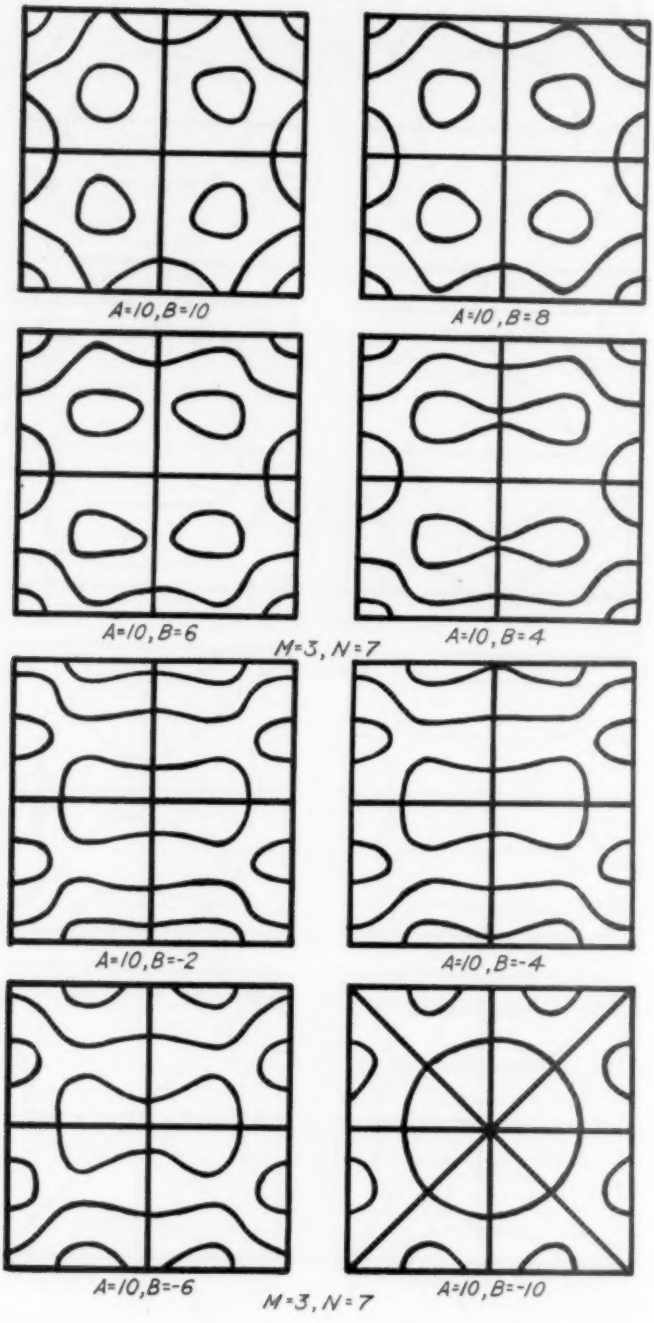

A=10, B=10
A=10, B=8
A=10, B=6
A=10, B=4
M=3, N=7
A=10, B=-2
A=10, B=-4
A=10, B=-6
A=10, B=-10
M=3, N=7

FIG. 4.

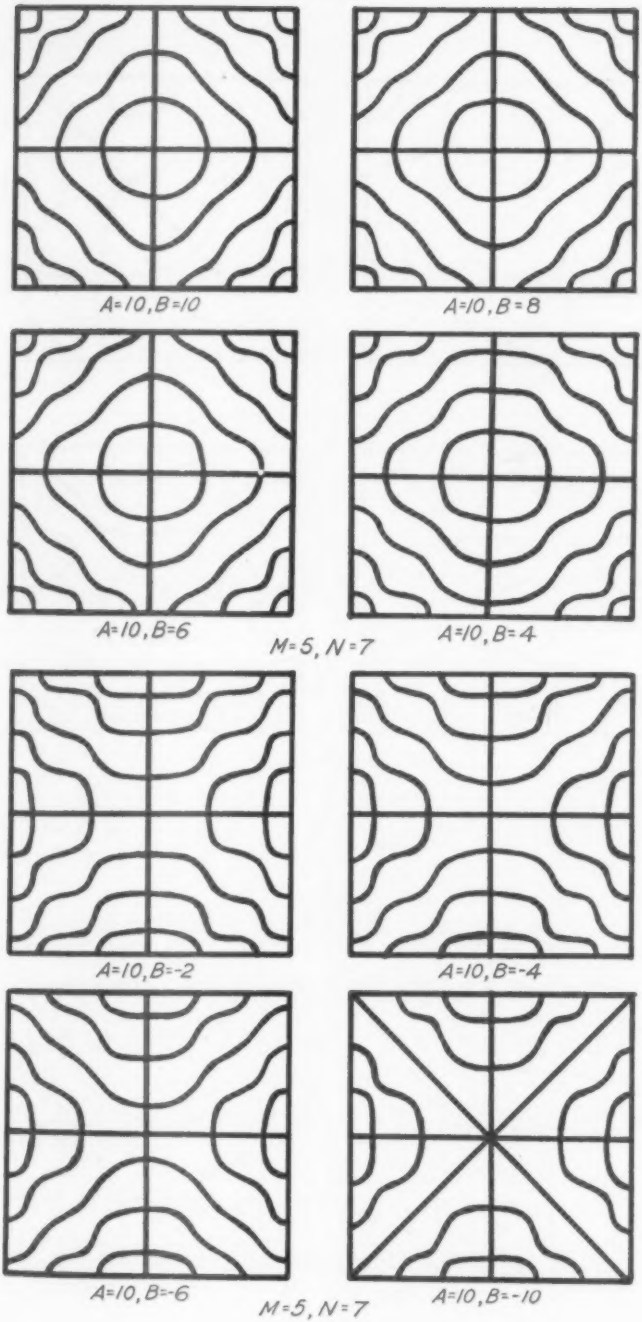
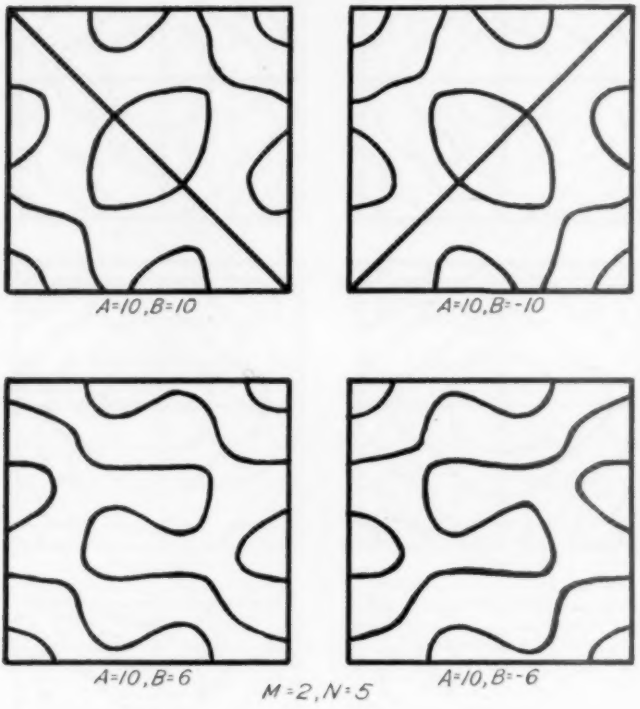

A=10, B=10
A=10, B=8
A=10, B=6
A=10, B=4
M=5, N=7
A=10, B=-2
A=10, B=-4
A=10, B=-6
A=10, B=-10
M=5, N=7

FIG. 5.



four equal squares, all of which have the same nodal lines. It is, therefore, possible to refer any even modes to lower vibrations in which m and n are not both even.

If m and n are both odd, the two median lines through the center are lines of no vibration, so that the plate again divides into four equal squares, but these cannot be referred to lower vibrations since m and n are always whole numbers.

If m is even and n odd, or vice versa, there is always one diagonal of the square which is a nodal line, provided $A = B$. The mirror image of such a figure is obtained by making $A = -B$. The mathematical proof of this proposition is easily demonstrated by observing that any point x, y is turned into x, $(a - y)$, in the mirror image. It is, therefore,

required to show that

$$A \cos\frac{m\pi x}{a}\cos\frac{n\pi(a-y)}{a} - B\cos\frac{n\pi x}{a}\cos\frac{m\pi}{a}(a-y) = 0 \tag{16}$$

is identical with (15) for m even and n odd or vice versa. Expanding (16) by trigonometric identities and making use of the relations $\sin m\pi = 0$, $\sin n\pi = 0$, $\cos m\pi = 1$, $\cos n\pi = -1$, we can reduce (16) to (15). All these relations are illustrated in the figures which follow.

In Fig. 2, m and n are both odd so that the characteristic median lines appear. The changes in the nodal lines are shown as the value of A changes from B to $-B$ through a series of values decided upon arbitrarily. For $A = 10$, $B = 10$ and $A = 10$, $B = -10$, the figures are well known, but the other figures have not heretofore been found experimentally because the plate was usually supported at the center and bowed at the edges. This method tended to make all the figures symmetrical with respect to the center and the four corners (i.e. to make $A = B$) but with the electrical valve oscillator,[4] many, but not all, of the intermediate figures have been discovered.

These diagrams are shown in Figs. 2, 3, 4 and 5, with the different values of A, B, m and n. In each figure, m and n are kept constant while A and B are varied.

Figures 6, 7, 8, 9, 10 and 11 are photographic reproductions of the nodal lines obtained by vibrating a brass plate 10 inches by 10 inches and 1/16 inch thick with the electrical oscillator. In Figs. 6, 7 and 8 the two upper photographs should be compared with one another and similarly for the lower.

In Figs. 9, 10 and 11, however, all the lines bear a close resemblance to one another. They show how a very slight change in the conformation of the nodal lines makes a complete change in the figure itself. According to the theory outlined here, each group, in Figs. 9, 10 and 11 has approxi-

[4] Colwell, Phil. Mag., Vol. XII, Suppl. Aug 1931, p. 320.

FIG. 6.

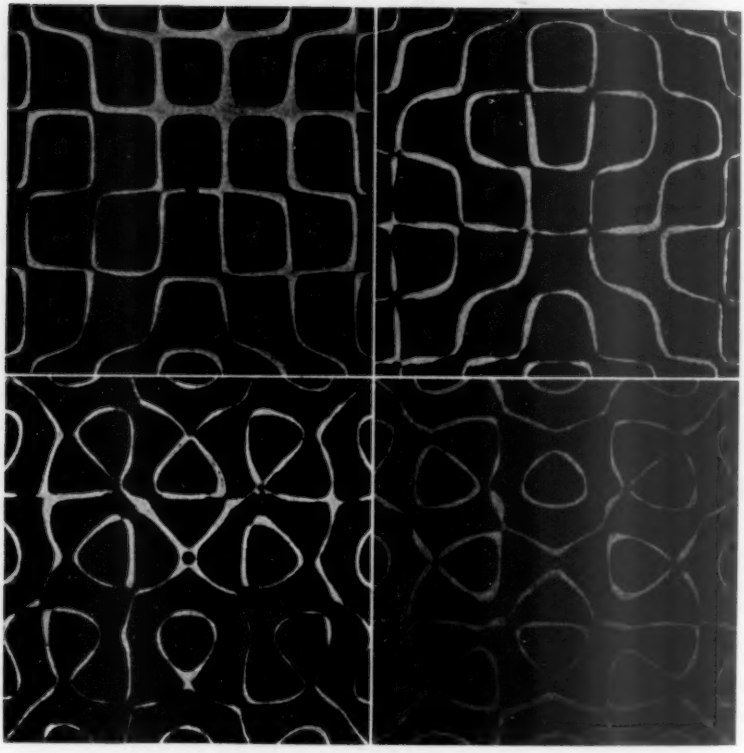


FIG. 7.

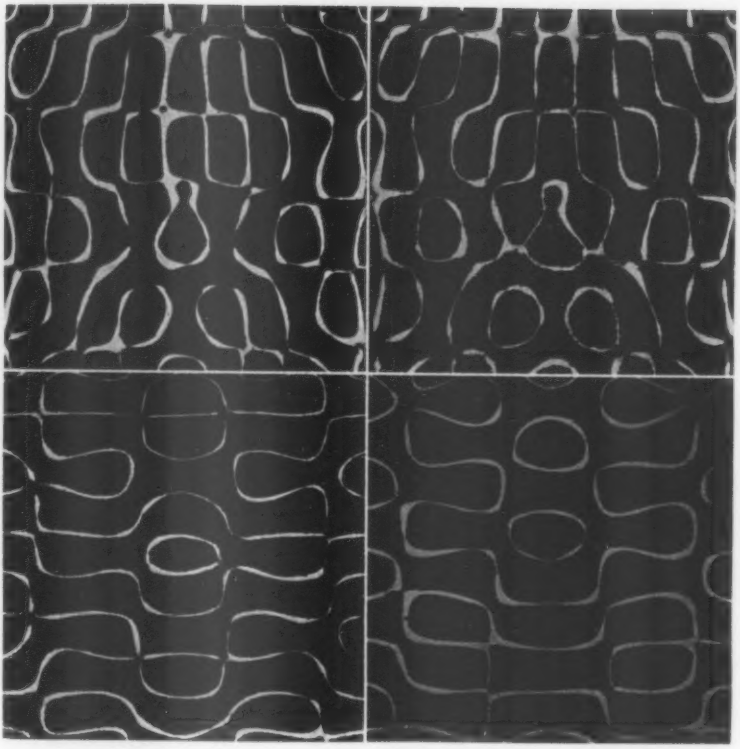


FIG. 8.

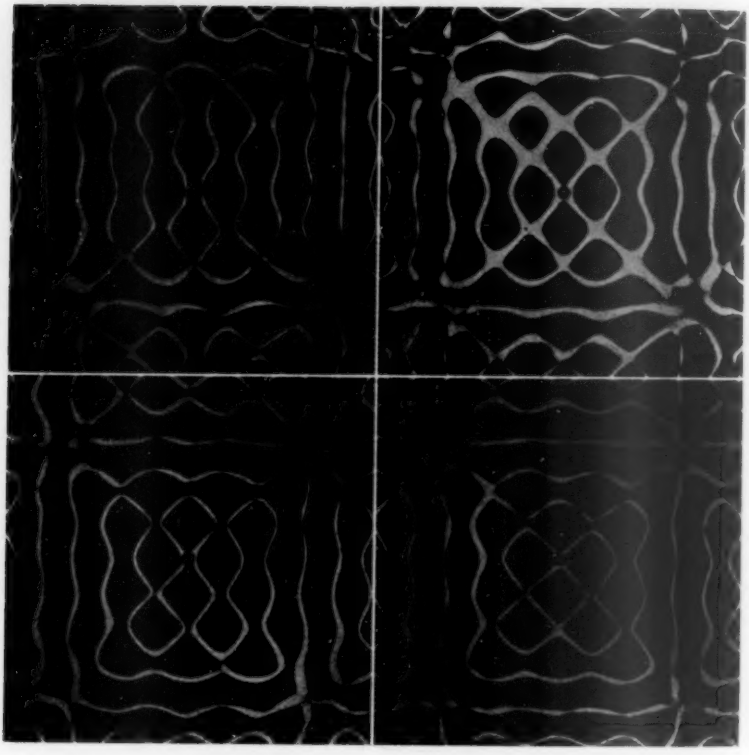


FIG. 9.

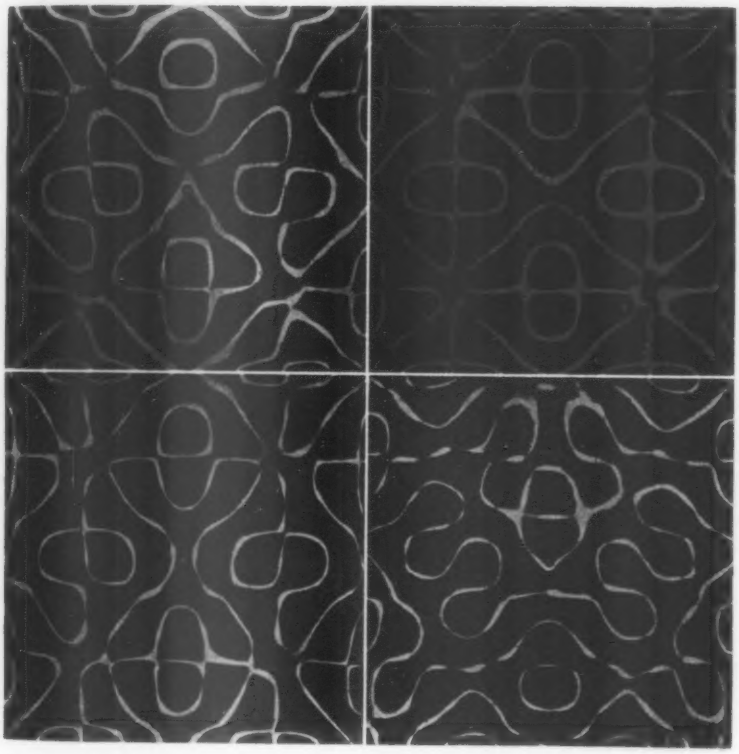


FIG. 10.

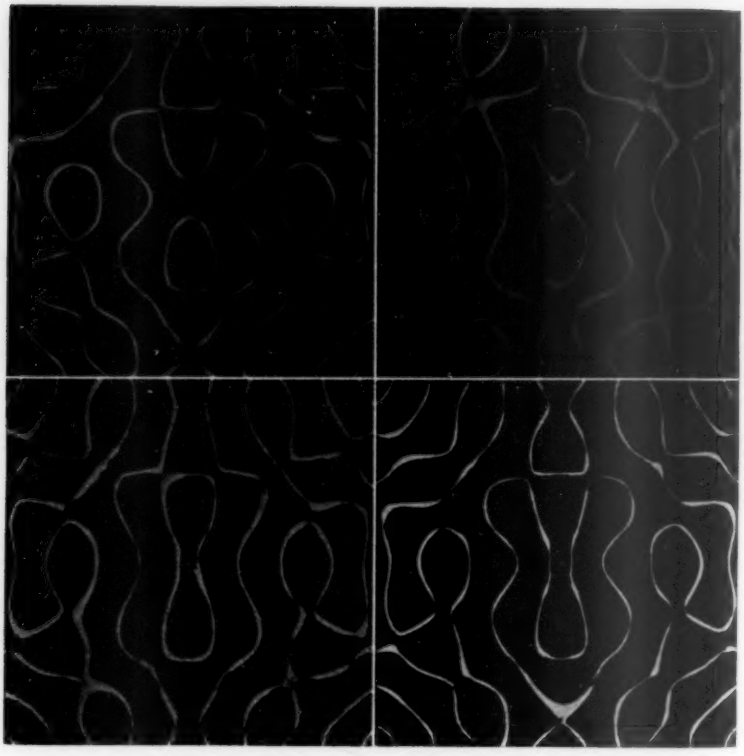
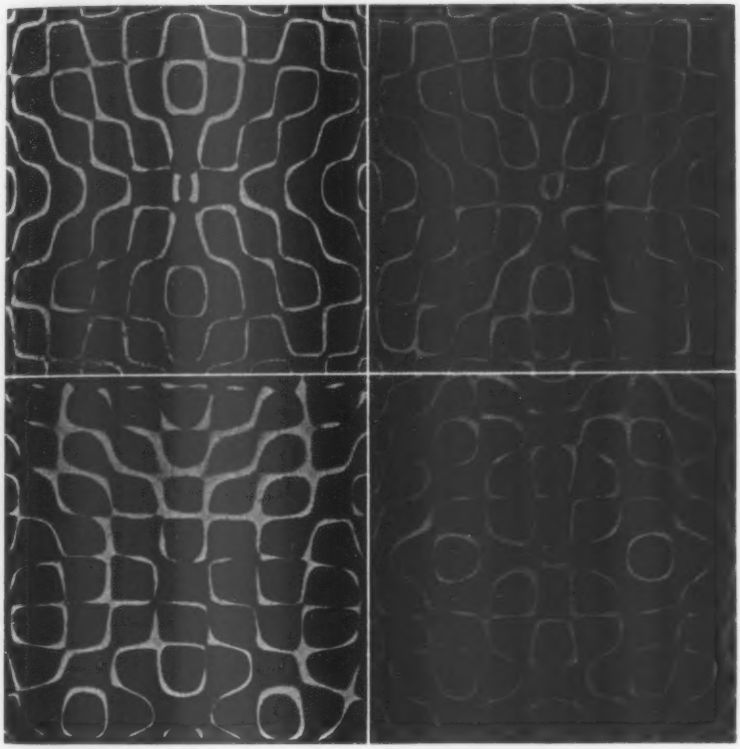


FIG. 11.



mately the same vibration, but the two terms of equation (15) are mixed in different proportions: in other words m and n remain nearly constant for each group, but A and B vary. If greater accuracy is desired, equation (13) should be used near the edges of the plate.

More About the Meuse Valley Catastrophe.—(News Edition, *Ind. & Eng. Chem.*, June 10, 1932.) There has recently been published in *L'Industrie Chimique Belge*, the report of a group of experts assigned by the magistrates of Liege to investigate the real reason for deaths among humans and animals presumably caused by a poisonous fog. Autopsies of several persons who died from these causes showed a diffuse congestion of the bronchi and of the mucous membrane of the trachea; fine black granules, which later were identified as particles of soot, were found in the alveoli of the lungs. Spectrographic tests for carbon monoxide in the blood were negative. Toxicological analyses and microscopic examination permit the authors to state that the fine particles of soot (0.5 to 1.35 microns) were inhaled by the victims during the last hour of their lives. Non-toxic themselves, it is possible—say two experts—that the fine particles of soot, on which the irritating gases were adsorbed, played a most significant part in the toxicity of the fog.

The general opinion seems to be that the sulfur dioxide, through its transformation into sulfurous acid and oxidation into sulfuric acid was responsible for the damage done. It also is pointed out that extremely fine particles of ferric oxide, zinc oxide and the like which are emitted by certain industrial plants in that vicinity could very readily act as catalysts in accelerating the oxidation. Although hydrofluoric acid was blamed at the time of the tragedy, a close study of weather conditions and distribution of the lethal vapors has demonstrated it to have played very little if any responsible part.

T. K. C.

THE MAGNETIC FIELD INTENSITY NEAR A CIRCULAR LOOP CARRYING AN ELECTRIC CURRENT.

BY

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Professor of Physics, University of Maine.

The magnetic field intensity on the axis of a circular loop carrying an electric current is well known. The magnetic field intensity in the plane of the loop and inside the loop has recently been worked out by Strom.[1] This paper is to show how a general formula may be obtained for the magnetic field intensity at *any point* near the loop.

An electric current is assumed to be flowing in the circle of Fig. 1. The magnetic field intensity is desired at a point P, not necessarily in the plane of the coil. A plane is passed through P normal to the plane of the circle. One point of intersection of this plane with the circle is A. A normal is dropped from P to the diameter extended through A. This distance from P to this diameter extended is b and the distance from the base of the normal to this diameter from P from A is d. The point P is at a distance h from A. The angle between the line from A to P and the diameter extended through A is β. The remaining lines and angles are clear from the figure.

An element of the circle of length dl is chosen and radii are drawn to its extremities as shown. From Ampere's Law the field intensity at P due to the current flowing in this element of arc is

$$dH = \frac{idl \sin \delta}{\rho^2} = \frac{ird\phi L}{\rho^3}.$$

This field intensity will have three components, dH_v normal to the plane of the coil, dH_h along the diameter through A, and dH_h' at right angles to this diameter.

[1] JOURNAL OF THE FRANKLIN INSTITUTE, 1928, p. 339.

These components may be written

$$dH_v = \frac{irLd\phi \cos \alpha}{\rho^3} = \frac{irLd\phi c}{\rho^3 L} = \frac{ircd\phi}{\rho^3},$$

$$dH_h = \frac{irLd\phi}{\rho^3} \sin \alpha \cos \phi = \frac{irLd\phi b}{\rho^3 L} \cos \phi = \frac{irb}{\rho^3} \cos \phi d\phi,$$

$$dH_h' = \frac{irLd\phi}{\rho^3} \sin \alpha \sin \phi = \frac{irLd\phi b}{\rho^3 L} \sin \phi = \frac{irb}{\rho^3} \sin \phi d\phi.$$

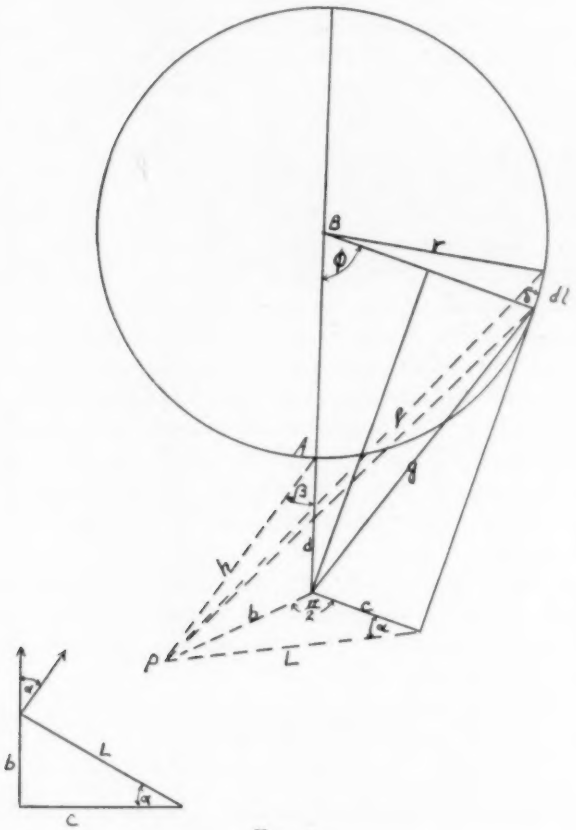


FIG. 1.

The last of these components dH_h' will have an equal and oppositely directed component from an element on the other

side of the diameter through A. It will then integrate to zero when the whole circle is considered. The other components will not integrate to zero in the general case.

Before these expressions can be integrated, it is necessary to express ρ in terms of ϕ, β, r, and h Thus

$$\begin{aligned}\rho^2 = b^2 + g^2 &= b^2 + c^2 + (r + d)^2 \sin^2 \phi \\ &= h^2 \sin^2 \beta + (r - (r + h \cos \beta) \cos \phi)^2 \\ &\qquad + (r + h \cos \beta)^2 \sin^2 \phi \\ &= h^2 + 2r^2 + 2rh \cos \beta - 2r(r + h \cos \beta) \cos \phi.\end{aligned}$$

Then

$$dH_v = \frac{ir(r - (r + h \cos \beta) \cos \phi)d\phi}{(h^2 + 2r^2 + 2rh \cos \beta - 2r(r + h \cos \beta) \cos \phi)^{3/2}}$$

and

$$dH_h = \frac{irh \sin \beta \cos \phi d\phi}{(h^2 + 2r^2 + 2rh \cos \beta - 2r(r + h \cos \beta) \cos \phi)^{3/2}}.$$

There is no common integral form similar to these. However, if $\theta = \pi - \phi$, $\cos \theta = -\cos \phi$ and $d\theta = -d\phi$ the equations become

$$dH_v = -\frac{ir(r + (r + h \cos \beta) \cos \theta)d\theta}{(h^2 + 2r^2 + 2rh \cos \beta + 2r(r + h \cos \beta) \cos \theta)^{3/2}}$$

and

$$dH_h = \frac{irh \sin \beta \cos \theta d\theta}{(h^2 + 2r^2 + 2rh \cos \beta + 2r(r + h \cos \beta) \cos \theta)^{3/2}}.$$

These are now similar to equation 306 in Pierce's Table of Integrals but the integration is laborious unless the steps are carried through in the general form to the final expression.

$$\begin{aligned}X &= \int_0^\pi \frac{(a' + b' \cos x)dx}{(a + b \cos x)^{3/2}} \\ &= \frac{2}{a^2 - b^2} \int_0^\pi \frac{((aa' - bb') - (ab' - a'b) \cos x)dx}{2(a + b \cos x)^{1/2}},\end{aligned}$$

since $\sin x = 0$ at each limit. Now let $\cos x = 1 - 2 \sin^2 x/2 = 1 - 2 \sin^2 \alpha$. Then $\alpha = x/2$ and $dx = 2d\alpha$ When these

are substituted in the above form there results

$$X = \frac{1}{a^2 - b^2}\int_0^{\pi/2} \frac{(aa' - bb' - ab' + 2ab' \sin^2\alpha + a'b - 2a'b \sin^2\alpha)2d\alpha}{(a + b - 2b \sin^2\alpha)^{1/2}}$$

$$= \frac{2}{a^2 - b^2}\left[\int_0^{\pi/2} \frac{(aa' - bb' - ab' + a'b)d\alpha}{(a + b - 2b \sin^2\alpha)^{1/2}} + \int_0^{\pi/2} \frac{(2ab' - 2a'b) \sin^2\alpha d\alpha}{(a + b - 2b \sin^2\alpha)^{1/2}}\right]$$

$$= \frac{2}{a^2 - b^2}\left[\int_0^{\pi/2} \frac{(a' - b')(a + b)d\alpha}{\left(1 - \frac{2b}{a + b} \sin^2\alpha\right)^{1/2}(a + b)^{1/2}} + 2\int_0^{\pi/2} \frac{(ab' - a'b) \sin^2\alpha d\alpha}{\left(1 - \frac{2b}{a + b} \sin^2\alpha\right)^{1/2}(a + b)^{1/2}}\right].$$

The first of these expressions is like formula 524 in Pierce's Table of Integrals and the second is like formula 569. Then

$$X = \frac{2}{(a - b)(a + b)^{3/2}}\left[\int_0^{\pi/2} \frac{(a' - b')(a + b)d\alpha}{(1 - k^2 \sin^2\alpha)^{1/2}} + \frac{2(ab' - a'b)}{2b/(a + b)}\left\{\int_0^{\pi/2} \frac{d\alpha}{(1 - k^2 \sin^2\alpha)^{1/2}} - \int_0^{\pi/2} (1 - k^2 \sin^2\alpha)^{1/2}d\alpha\right\}\right].$$

$$X = \frac{2}{(a - b)(a + b)^{3/2}}\left[(a' - b')(a + b)K + \frac{(a + b)}{b}(ab' - a'b)(K - E)\right],$$

$$X = \frac{2}{(a - b)(a + b)^{1/2}}\left[\left(a\frac{b'}{b} - b'\right)K - \left(a\frac{b'}{b} - a'\right)E\right],$$

$$X = \frac{2}{(a - b)(a + b)^{1/2}b}[b'(a - b)K - (ab' - a'b)E].$$

In these equations K and E are quantities whose values depend upon k^2 which is given by the ratio of $2b/(a + b)$. A table of these values is given in Pierce's Table of Integrals.

By means of this general formula the integrations for H_v and H_h are much simplified. The final results are

$$H_v = \frac{-2i(hK - (h + 2r\cos\beta)E)}{h(h^2 + 4r^2 + 4rh\cos\beta)^{1/2}},$$

where

$$k^2 = \frac{4r(r + h\cos\beta)}{h^2 + 4r^2 + 4rh\cos\beta}$$

and

$$H_h = \frac{2i\sin\beta(h^2K - (h^2 + 2r^2 + 2rh\cos\beta)E)}{h(h^2 + 4r^2 + 4rh\cos\beta)^{1/2}(r + h\cos\beta)}.$$

These equations give the normal and horizontal components of the magnetic field intensity at any point near a circular loop carrying an electric current.

If β is set equal to zero, expressions are obtained for the field intensity outside the loop and in its plane. These are

$$H_v = \frac{-2i(hK - (h + 2r)E)}{h(h^2 + 4r^2 + 4rh)^{1/2}}$$

and $H_h = 0$ since $\sin\beta = 0$ and

$$k^2 = \frac{4r(r + h)}{h^2 + 4r^2 + 4rh}.$$

If now h is assumed very small to r

$$H_v = \frac{2i2rE}{h2r} = \frac{2iE}{h},$$

but in this case K approaches one and E approaches one. So in the limiting case

$$H_v = 2i/h,$$

as might have been expected.

If, however, h is very great to r

$$H_v = \frac{-2ih(K - E)}{h^2} = \frac{-2i(K - E)}{h}.$$

In the limiting case k approaches zero and K and E each

approach $\pi/2$ so that H_v approaches zero also. If $h = r$

$$H_v = \frac{-2ih(K-3E)}{h3h} = \frac{-2i(K-3E)}{3h}.$$

In this case $k^2 = 8/9$, $k = .9428$, $K = 2.5292$, $E = 1.1137$. Then

$$H_v = \frac{2i.8119}{3h} = .5412i/h.$$

The last figure is doubtful since it was necessary to interpolate to get the above values of K and E.

If β is set equal to π, equations are found for the field intensity inside the loop and in its plane. As before $\sin \beta = 0$ so the horizontal component becomes zero. The vertical component becomes

$$H_v = \frac{-2i(hK-(h-2r)E)}{h(h^2+4r^2-4rh)^{1/2}}$$

where

$$k^2 = \frac{4r(r-h)}{h^2+4r^2-4rh}.$$

When h is very small to r, k approaches one, E approaches one and K is very large. If hK may be neglected as compared to $2rE$

$$H_v = \frac{-2i2rE}{h2r} = \frac{-2iE}{h} = -2i/h$$

as was expected. If $h = r$

$$H_v = \frac{-2ih(K+E)}{h^2}.$$

But in this case $k = 0$ and $K = E = \pi/2$, so that

$$H_v = -2\pi i/h = -2\pi i/r,$$

as was expected.

As a check on the field intensity outside the plane of the coil, take a point, P, on the axis of the coil. Then $\sin \beta = b/h$ and $\cos \beta = -r/h$. These in turn make $k = 0$ and $K = E$

$= \pi/2$. Then

$$H_v = \frac{-2i\,(hK-(h-2r^2/h)E)}{h(h^2+4r^2-4r^2)^{1/2}} = \frac{-2\pi i r^2}{h^3},$$

which is the correct result, as is well known. If the formulæ are correct the horizontal component of the field intensity should be zero. To test this, substitution is made in the formula and the result comes out indeterminate. However if instead of setting $k = 0$ we set $k = \alpha$, a very small quantity and instead of using $K = E = \pi/2$ we use the series from which K and E result, H is found to vanish as α vanishes.

The field intensity in the surface of a right circular cylinder coaxial with the coil may be found by placing $\beta = \pi/2$. Then $\cos\beta = 0$ and $\sin\beta = 1$. This makes

$$H_v = \frac{-2i(hK-hE)}{h(h^2+4r^2)^{1/2}} = \frac{-2i(K-E)}{(h^2+4r^2)^{1/2}} \qquad k^2 = \frac{4r^2}{h^2+4r^2}$$

and

$$H_h = \frac{2i(h^2K-(h^2+2r^2)E)}{h(h^2+4r^2)^{1/2}r}.$$

When h is very small to r, k approaches 1, E approaches 1, and K becomes very large. Again if hK may be neglected as compared to $2rE$,

$$H \text{ approaches } -2i/h.$$

In the following table the values of the vertical component are given for a few points very near the coil.

k.	K.	E.	H.
.9998	5.4349	1.0009	$4.4340i/r$
.9994	4.7427	1.0026	3.7401
.9986	4.3387	1.0053	3.3334
.9976	4.0528	1.0086	3.0442

These equations are now being tested experimentally by some of my students and check very well as far as the tests have gone.

What Sugar Is Good For.—(News Edition, *Ind. & Eng. Chem.*, June 10, 1932.) Growers and refiners of cane sugar, more accurately termed " sucrose " are searching for additional uses to which their product may be put other than that of sweetening and preserving foods. Accordingly a Sugar Fellowship has been established at Mellon Institute of Industrial Research and at present is held by G. J. Cox and John Metschl who submit a report on the progress made to this date.

The investigation may be divided into three sections: sucrose derivatives, degradation products and direct uses of the sugar. Among the derivatives, the best known probably is that obtained by combining acetic anhydride with sugar to give necrose octa-acetate. Its cost of manufacture is relatively low and the product has characteristics indicating its use as a gum constituent of lacquers, as a plasticizer and an ingredient of anhydrous adhesives. It has an exceedingly bitter taste and can be detected in a concentration of 1 and 2 parts per million of water. The most interesting of the degradation products probably is levulinic acid prepared by heating sucrose under pressure with hydrochloric acid. Esters of this acid have been prepared; the one resulting from its combination with ethyl alcohol possesses a very pleasant watermelon-like odor. These esters rapidly dissolve nitrocellulose.

Among the direct uses, the mixing of sugar in lime-sand mortar seems to be the most promising from the standpoint of quantity consumption. Test data definitely indicate an increase of about 60 per cent. in tensile strength with the addition of sugar amounting to 6 per cent. of the quicklime. Recommendations based on experience call for 6 pounds sugar per 100 pounds quicklime or 4.5 pounds per 100 of hydrated lime. Important: the lime must be slaked and cool before sugar is added. It seems well established that cane sugar ruins concrete made from Portland cement and must not be used.

T. K. C.

A METHOD FOR THE CALCULATION OF THE CORRECT AND MOST ECONOMICAL CONCENTRATIONS OF ELON AND HYDROQUINONE IN A BORAX DEVELOPER FOR MOTION PICTURE FILM.

BY

ALAN M. GUNDELFINGER, B.S. in Ch.E.

ABSTRACT.

Holding temperature, developing time, and agitation constant, the following relations exist:

1. In an Elon-borax-sulfite developer, sulfite held constant and borax varied with the Elon,

$$\gamma = K \log E + C,$$

where E = Elon conc. and K and C = constants.

2. In an Elon-hydroquinone-borax-sulfite developer, hydroquinone and sulfite held constant and borax varied with the Elon,

$$\gamma = K \log E + C,$$

where E = Elon conc. and K and C = constants.

3. In an Elon-hydroquinone-borax-sulfite developer, Elon, borax and sulfite held constant,

$$\gamma = K \log H + C,$$

where H = hydroquinone conc. and K and C = constants.

4. In an Elon-hydroquinone-borax-sulfite developer, sulfite held constant and borax varied with the Elon,

$$\gamma = K_1 \log E + K_2(\log E)(\log H) + K_3 \log H + K_4,$$

where E = Elon conc., H = hydroquinone conc., and K_1, K_2, K_3, K_4 = constants.

5. In an Elon-hydroquinone-borax-sulfite developer, γ and sulfite held constant, and borax varied with the Elon, there exist optimum concentrations of Elon and hydroquinone for maximum economy.

Carlton and Crabtree [1] have stated, "If borax is added to convert the Elon into the Elon base, the rate of development increases with the Elon concentration. The gamma produced for a constant time of development increases as a linear function of the logarithm of the Elon concentration."

[1] "Some Properties of Fine Grain Developers for Motion Picture Film," by H. C. Carlton and J. I. Crabtree, *Trans. Soc. Mot. Pict. Eng.*, Vol. XIII, No. 38, 1929, pp. 406–440.

The purposes of this investigation were as follows:

1. To verify the statement of Carlton and Crabtree concerning the exponential relation between Elon and gamma in an Elon-borax-sulfite developer.
2. To determine whether or not the same, or any other relation exists between Elon and gamma in an Elon-hydroquinone-borax-sulfite developer (hydroquinone maintained constant).
3. To determine the relation between hydroquinone and gamma, if any, in an Elon-hydroquinone-borax-sulfite developer (Elon maintained constant).
4. To determine, if possible, the relation between gamma, Elon, and hydroquinone in an Elon-hydroquinone-borax-sulfite developer (Elon and hydroquinone both variable).
5. To derive a method for calculation of the most economical concentrations of Elon and hydroquinone, provided that the function of gamma, Elon and hydroquinone can be evaluated.

I. LABORATORY PROCEDURE.

(a) Film Stock.

In performing the series of tests for this investigation it was thought advisable to use negative stock, which reacts considerably better with borax developers and has greater latitude than positive stock, and to use one with which a fair amount of light could be used in the dark room. Consequently, Eastman Orthochromatic No. 1201–171 was chosen.

(b) Sensitometric Exposures.

Sensitometric strips were exposed on an Eastman Type II*b* sensitometer with a lamp and filter accurately calibrated, by the Eastman Kodak Co., as to intensity and color temperature (5400 deg. K) and a time scale in powers of $\sqrt{2}$.

(c) Development.

Development of the sensitometric strips was performed in the following manner:

Two strips were fastened, emulsion side up and adjacent to each other, to a piece of plate glass. The plate of glass

was dropped, simultaneously with the releasing of a timing device, into a tray containing just sufficient developer to cover the strips. The temperature of the developer was maintained at 18 ± 1 deg. C. Immediately after dropping the plate of glass into the developer, brushing of the strips was started. A camel's-hair brush, wide enough to cover both strips, was used and the brushing was accomplished with a uniform reciprocating stroke of length equal to that of the strips. The rate of brushing was maintained as constant as is humanly possible. At the instant of the sounding of the time signal, indicating completion of the required development time, the glass plate with its attached strips was transferred bodily to an adjacent tray containing hypo solution, after which the strips were thoroughly washed and dried. The time of development, in all cases, was maintained at 5.0 minutes and the time of hypo immersion was considerably more than sufficient for the complete removal of all undeveloped silver halide.

(d) Density Determinations.

Densities on the developed sensitometric strips were determined with a Western Electric densitometer using a Bausch and Lomb head of the polarizing type. The observations were made with the emulsion side of the strips downward, against the diffusion glass.

(e) Curve Plotting.

In plotting the H. and D. curves, the average density of corresponding exposures, on two strips developed simultaneously, was plotted against the $\log_{10}$ of the absolute exposure.

(f) Developers.

All developers used in this investigation contained 300.0 gm. of sodium sulfite per gallon and a quantity per gallon, of borax, equal to the weight of Elon, in grams per gallon, plus 8.0. In explanation, it might be well to call attention to the fact that since Elon requires approximately an equal quantity, by weight, of borax in order to be converted into the Elon base,[1] this arrangement was utilized so that a theoretical excess of 8.0 gm. of free borax would always be available to accommodate the slightly low pH value of hydroquinone without seriously affecting the pH value of the developer.

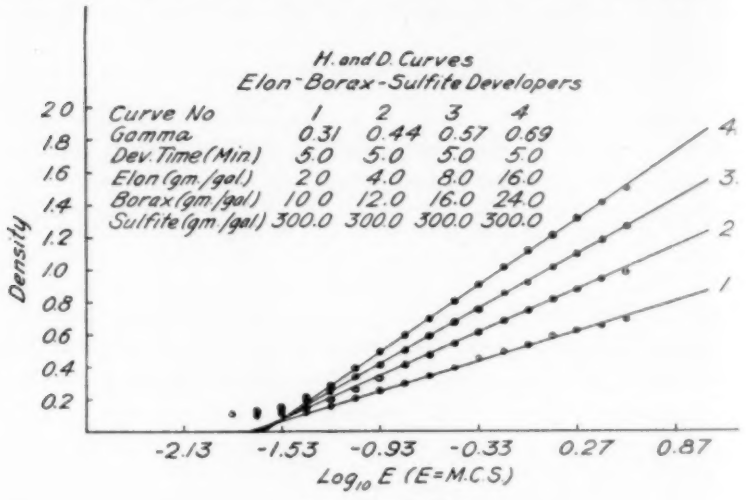
The four fundamental developers used were as follows:

Developers.	1	2	3	4
Elon (gm./gal.)	2.0	4.0	8.0	16.0
Borax (gm./gal.)	10.0	12.0	16.0	24.0
Sulfite (gm./gal.)	300.0	300.0	300.0	300.0

In addition, sixteen more developers were used consisting of each of the above-tabulated developers containing, in addition, 2.0, 4.0, 8.0 and 16.0 gm., respectively, of hydroquinone per gallon.

II. RELATION BETWEEN GAMMA AND ELON IN AN ELON-BORAX-SULFITE DEVELOPER.

Curve diagram No. 1 shows the H. and D. curves obtained from the four fundamental developers without hydroquinone.

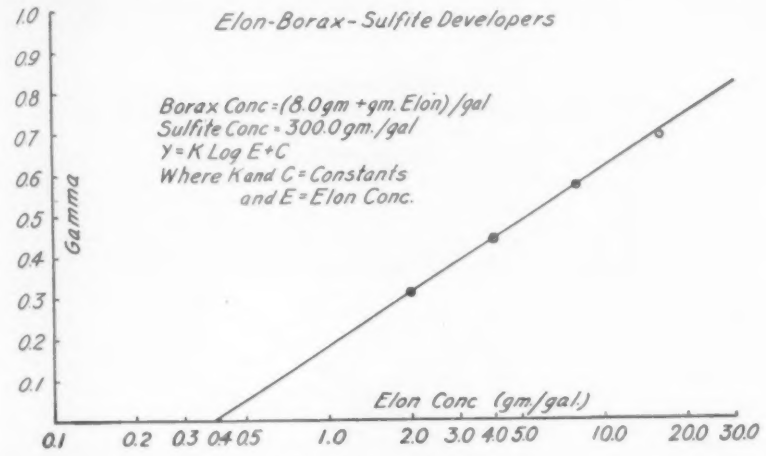


Curve Diagram No. 1.

Curve diagram No. 2 shows the curve obtained by plotting gamma against log Elon concentration. Examination of the curve reveals the fact that the general equation is:

$$\gamma = K \log E + C, \tag{1}$$

where K and C = constants and E = Elon concentration.



Curve Diagram No. 2.

Evaluating the constants of the equation for the curve best representing the data, the following equation is obtained:

$$\gamma = 0.432 \log_{10} E + 0.18.$$

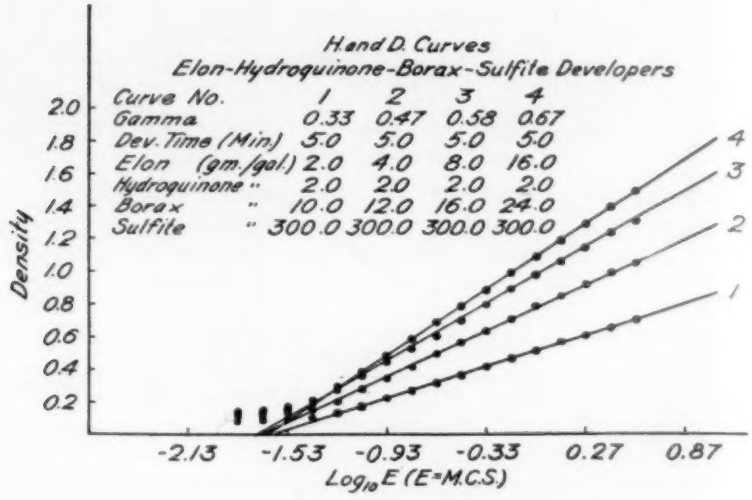
If, now, in equation (1), γ is differentiated with respect to E, then,

$$\frac{d\gamma}{dE} = \frac{K}{E} \tag{2}$$

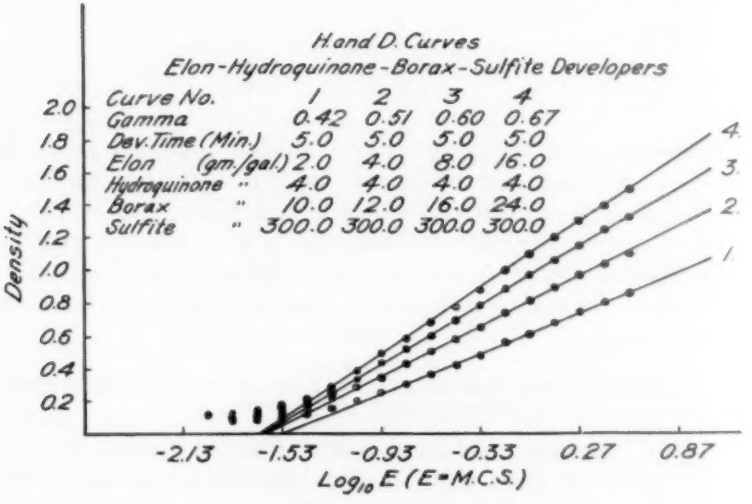
or the derivative or slope of the γ-Elon function curve is inversely proportional to the Elon concentration and the proportionality constant is the slope of the γ-log E curve. In other words, the rate of change of γ with respect to Elon concentration, holding temperature, agitation and development time constant, is inversely proportional to the Elon concentration.

III. RELATION BETWEEN GAMMA AND ELON IN AN ELON-HYDROQUINONE-BORAX-SULFITE DEVELOPER.

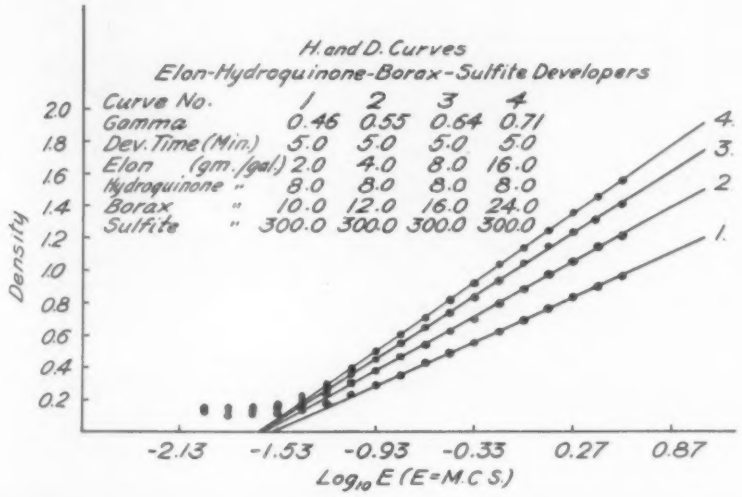
Curve diagrams No. 3, 4, 5 and 6 show the H. and D. curves obtained from the four fundamental developers containing 2.0, 4.0, 8.0 and 16.0 gm. hydroquinone, respectively. Curve diagram No. 7 shows the curves obtained by plotting gamma against log E in the presence of constant concentra-



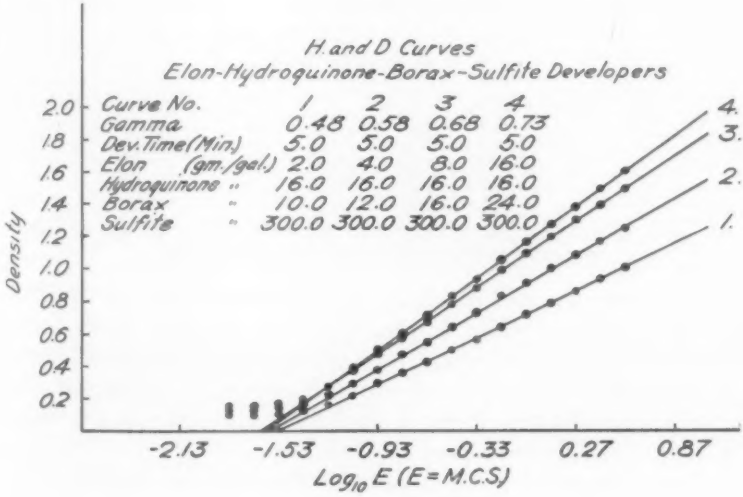
Curve Diagram No. 3.



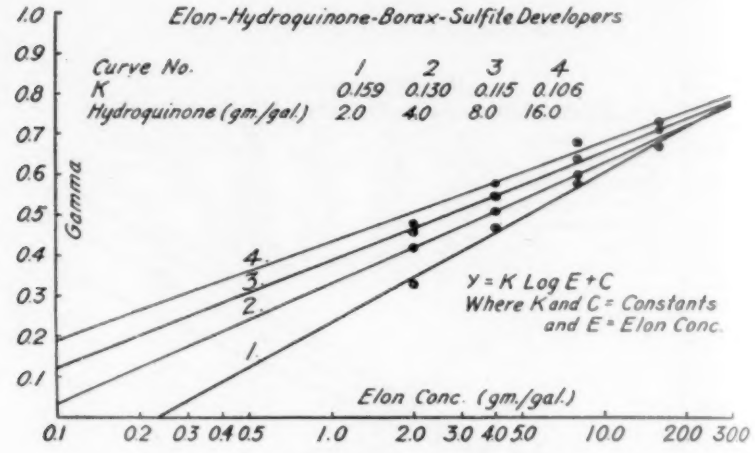
Curve Diagram No. 4.



Curve Diagram No. 5.



Curve Diagram No. 6.



Curve Diagram No. 7.

tions of hydroquinone. It can be observed quite readily that the same general relation exists between γ and Elon concentration, in the presence of a fixed concentration of hydroquinone, as exists in the absence of the latter. That relation may be represented also by:

(1) $$\gamma = K \log E + C$$

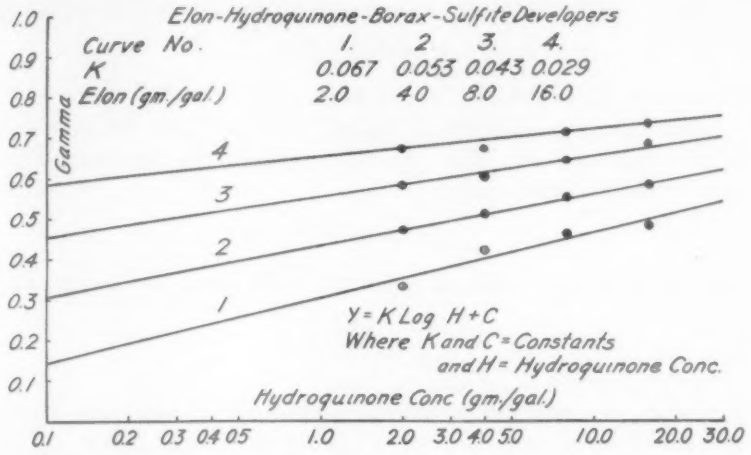
and

(2) $$\frac{d\gamma}{dE} = \frac{K}{E}.$$

IV. RELATION BETWEEN GAMMA AND HYDROQUINONE IN AN ELON-HYDROQUINONE-BORAX-SULFITE DEVELOPER.

Inasmuch as the reaction of hydroquinone, as well as other developing agents, on the silver halide grain, is primarily one of reduction, the mechanics of which should in all cases be similar, if not exactly the same, it should be expected that the relation between gamma and hydroquinone is the same as that between the former and Elon.

Curve diagram No. 8 shows the curves obtained by plotting gamma against log hydroquinone concentration, in the presence of constant concentrations of Elon. The data for these curves were obtained, likewise, from those of curve



Curve Diagram No. 8.

diagrams Nos. 3, 4, 5 and 6. As was to be expected, it can be observed, quite readily, that the same general relation exists between gamma and hydroquinone, in the presence of a constant concentration of Elon, as exists between gamma and Elon, in the presence of a fixed concentration of hydroquinone. This relation may be represented by:

$$\gamma = K \log H + C \tag{3}$$

and

$$\frac{d\gamma}{dH} = \frac{K}{H}, \tag{4}$$

where K and C = constants and H = hydroquinone concentration.

V. RELATION BETWEEN GAMMA, ELON AND HYDROQUINONE IN AN ELON-HYDROQUINONE-BORAX-SULFITE DEVELOPER.

In III and IV it has been shown that, holding temperature, agitation, development time and the concentration of the remaining constituents constant,

$$\gamma = F(E) \quad \text{and} \quad \gamma = f(H)$$

and $F(E)$ and $f(H)$ have been evaluated.

Then, if

$$\gamma = F(E, H)$$

it becomes highly desirable to evaluate $F(E, H)$.

Examination of curve diagram No. 7 reveals the fact that K of equations (1) and (2) varies with the hydroquinone concentration such that

$$K = \psi(H)$$

and equation (2) becomes a partial differential equation, as

$$\frac{\partial \gamma}{\partial E} = \frac{\psi(H)}{E}. \tag{5}$$

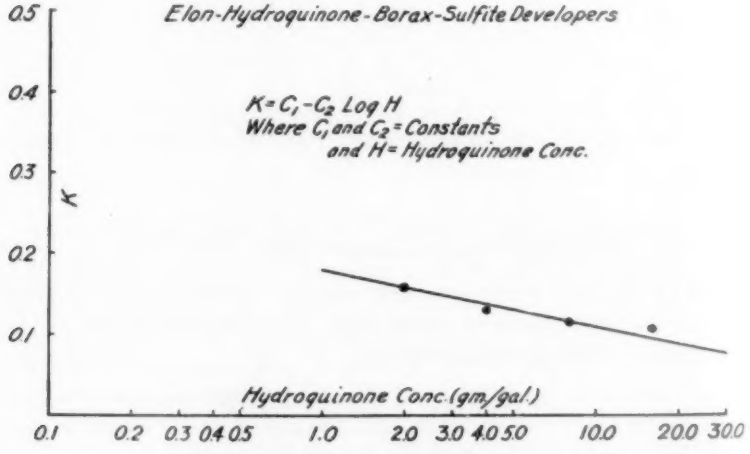
Likewise, it may be observed from curve diagram No. 8 that K of equations (3) and (4) is a function of E, or

$$K = \phi(E),$$

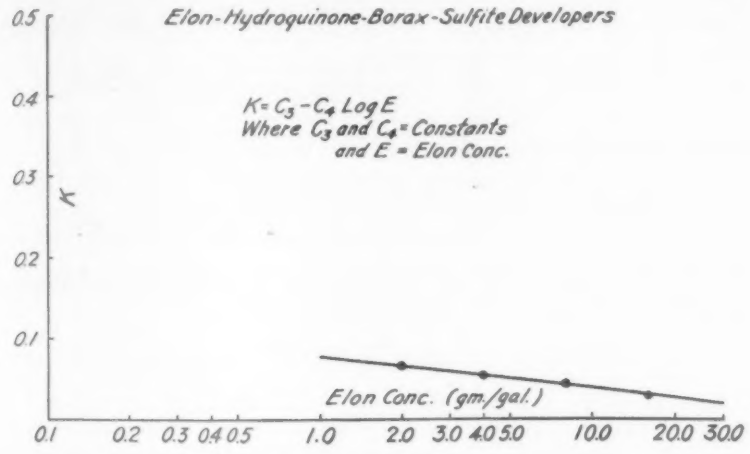
such that equation (4) becomes a partial differential equation, as

$$\frac{\partial \gamma}{\partial H} = \frac{\phi(E)}{H}. \tag{6}$$

If, then, K of equations (1) and (2) is plotted against log H, as shown on curve diagram No. 9, it is found that



Curve Diagram No. 9.



Curve Diagram No. 10.

there is a linear relation between K and $\log H$, and $\psi(H)$ can be evaluated. Then:

$$K = \psi(H) = C_1 - C_2 \log H. \tag{7}$$

Similarly, K of equations (3) and (4) is shown, on curve diagram No. 10, to bear a linear relation to $\log E$ such that

$$K = \phi(E) = C_3 - C_4 \log E, \tag{8}$$

where C_1, C_2, C_3 and C_4 are constants.

Combining equations (5) with (7) and (6) with (8), there results

$$\frac{\partial \gamma}{\partial E} = \frac{\psi(H)}{E} = \frac{C_1 - C_2 \log H}{E} \tag{9}$$

and

$$\frac{\partial \gamma}{\partial H} = \frac{\phi(E)}{H} = \frac{C_3 - C_4 \log E}{H}. \tag{10}$$

Integrating (9),

$$\gamma = (C_1 - C_2 \log H) \log E + f(H). \tag{11}$$

Differentiating γ with respect to H in (11),

$$\frac{\partial \gamma}{\partial H} = -\frac{C_2 \log E}{H} + \frac{df}{dH}. \tag{12}$$

Combining equations (10) and (12),

$$(13)\quad \frac{df}{dH} = \frac{C_3 - C_4 \log E}{H} + \frac{C_2 \log E}{H} = \frac{C_3 + C_5 \log E}{H},$$

which on integration gives

$$(14)\quad f(H) = (C_3 + C_5 \log E) \log H + C_6 = C_3 \log H + C_5(\log E)(\log H) + C_6,$$

where C_6 = constant of integration. And on combining equations (11) and (14) there results

$$(15)\quad \gamma = C_1 \log E + C_7(\log E)(\log H) + C_3 \log H + C_6,$$

or

$$(16)\quad \gamma = K_1 \log_{10} E + K_2(\log_{10} E)(\log_{10} H) + K_3 \log_{10} H + K_4.$$

Equation (15) becomes, then, the general equation for

$$\gamma = f(E, H),$$

and evaluating the constants from the experimental data, the equation for the set of conditions in this series of tests becomes

$$(17)\quad \gamma = 0.402 \log_{10} E - 0.114(\log_{10} E)(\log_{10} H) + 0.217 \log_{10} H + 0.174,$$

where E = Elon concentration in gm. per gallon and H = hydroquinone concentration in gm. per gallon.

VI. A METHOD FOR THE CALCULATION OF THE MOST ECONOMICAL CONCENTRATIONS OF ELON AND HYDROQUINONE IN AN ELON-HYDROQUINONE-BORAX-SULFITE DEVELOPER.

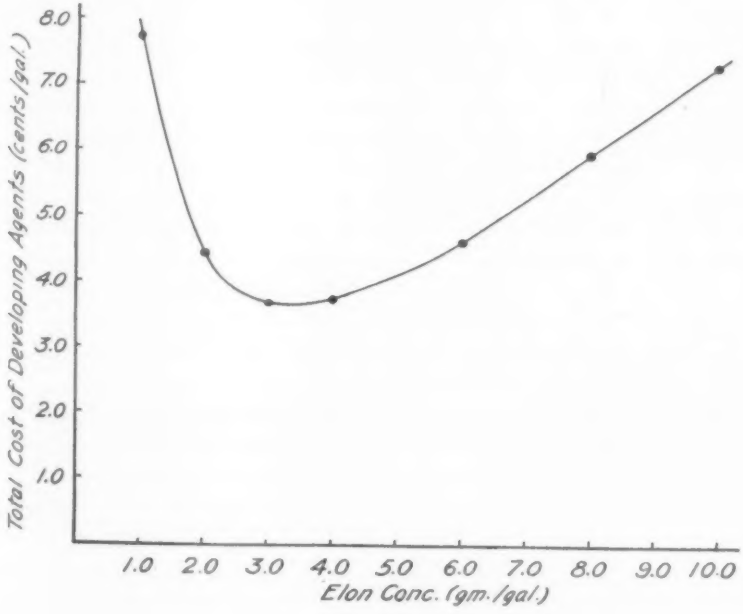
An analysis of equation (15) of part V reveals the fact that an infinite number of combinations of Elon and hydroquinone will satisfy the equation for any definite gamma. The question then arises as to the optimum concentration for the two developing agents. The natural answer to that question is that combination of concentrations which will formulate the least expensive developer.

At present there is a marked difference in the prices of Elon and hydroquinone, that of the former amounting to

slightly over three times that of the latter. The natural impulse would lead to the conclusion, then, that the least expensive developer would comprise one of the least possible amount of Elon.

Such, however, is not the case, for a glance at the slopes of the curves on curve diagrams Nos. 7 and 8 will reveal the fact that Elon is much the more powerful reducing or developing agent. Consequently, while it is the more expensive of the two agents, a lesser concentration of it is required to produce a definite degree of development than that of hydroquinone. On the other hand, it is possible to utilize a concentration of Elon which is too high for economy.

In order to illustrate this point, let the assumption be made that the costs of Elon and hydroquinone are $3.30 per pound and $1.00 per pound, respectively, and that the desired gamma is 0.5. Then by virtue of this assumption and equation (17), a curve (curve diagram No. 11) has been constructed showing the relation between the total cost of



Curve Diagram No. 11.

developing agents per unit volume of developer and the concentration of Elon.

It is apparent that the curve has a marked minimum point and that there are distinct optimum concentrations of both developing agents for maximum economy. It is perfectly possible to determine the minimum point of this curve, analytically, making use of the calculus, but for all practical purposes, the increased accuracy is of no value and does not warrant the procedure which is quite laborious.

From the curve, it is seen that an Elon concentration of 3.3 gm. per gallon corresponds to the least cost of a developer which complies with the previously mentioned assumptions and is to be utilized under the precise experimental conditions of this investigation. The corresponding hydroquinone concentration is found from equation (17) to be 5.5 gm. per gallon.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

GEORGE KIMBALL BURGESS.

The death of Dr. George Kimball Burgess, director of the Bureau of Standards, occurred suddenly on the morning of July 2. Doctor Burgess was stricken at his desk and death came within an hour afterward. The immediate cause was a cerebral hemorrhage, following a similar attack last October.

Doctor Burgess was born at Newton, Mass., January 4, 1874, and came of an old and distinguished New England family. He was educated at the public schools of his native town and received the degree of Bachelor of Science from Massachusetts Institute of Technology in 1896. He pursued advanced scientific courses at the University of Paris from 1898 to 1900, and in 1901 that institution conferred upon him the degree of Doctor of Sciences with mention "tres Honorable," the highest grade of commendation given with the doctor's degree. His thesis was a redetermination of the constant of gravitation, using the torsion balance. From the time of his graduation Doctor Burgess was a constant student of the physical sciences and has left a reputation for exact and brilliant work in many fields. After the completion of his studies at the University of Paris, Doctor Burgess served on the faculties of the University of Michigan and the University of California.

On June 8, 1903, he entered the service of the Bureau of Standards, only two years after its establishment. He achieved an international reputation in the fields of high temperature measurement and metallurgy, being the first to use the optical pyrometer for the accurate measurement of the temperature of railroad rails during the process of hot rolling.

With his colleague, Dr. C. W. Waidner, then chief of the heat division of the bureau, he suggested in 1908 a natural reproducible standard of light based upon the black body

* Communicated by the Director.

radiation of a hollow tube immersed in molten platinum. (*Technical News Bulletin* No. 151, p. 107 and No. 170, p. 62.) After 24 years this is now recognized as one of the most fundamental and practical contributions to the field of photometry, and seems likely to be adopted as an international standard.

Upon the organization of the bureau's division of metallurgy in 1913, Doctor Burgess was appointed its chief by the director, Dr. S. W. Stratton. During the World War Doctor Burgess was sent on a special mission to France where he obtained data concerning the most urgent types of research which should be taken up in this country. His duties carried him into the actual fighting lines and the firsthand information thus secured proved later to be invaluable.

In April, 1923, Doctor Burgess was appointed by President Harding to the post of director of the Bureau of Standards, to succeed Doctor Stratton who had accepted the presidency of Massachusetts Institute of Technology. In the nine years of Doctor Burgess' administration the bureau has grown in the value and variety of its work. He was particularly interested in every field in which the bureau could coöperate with American industries towards the solution of scientific and technical problems, and it was under his guidance that the research associate plan, by which industrial organizations are enabled to send to the bureau, experts to work on problems in their particular fields, was developed. This research associate plan has proved one of the most valuable ways in which the Government coöperates with American manufacturers and has assured the prompt application of research results to manufacturing processes with a better and less expensive finished product.

The welfare of the bureau's staff was always uppermost in Doctor Burgess' mind. He did much to promote its efficiency and to improve working conditions. Under his administration the value of the advanced educational courses conducted out of hours for the benefit of the younger members of the staff, was greatly increased. In giving full credit to junior collaborators in scientific work under his direction he set an example to be followed by every one.

At the time of his death Doctor Burgess was president of the National Conference on Weights and Measures, and chairman of the Federal Specifications Board, the National Screw Thread Commission, and the Federal Fire Council. His term of office as chairman of the National Research Council had expired on June 30. He was a past president of the American Society for Steel Treating, the Philosophical Society of Washington, the Washington Academy of Sciences, the American Society for Testing Materials, and the Cosmos Club. He was an honorary member of the American Foundrymen's Association and the Japanese Society of Mechanical Engineers, a director of the American Standards Association, a fellow of the American Association for the Advancement of Science, and a member of Sigma Xi fraternity. In addition, he was a member of the National Academy of Sciences, American Institute of Mining and Metallurgical Engineers, National Advisory Committee for Aeronautics, Optical Society of America, American Physical Society, American Institute of Metals, the French Physical Society, and the Iron and Steel Institute of Great Britain.

In addition to his degrees from Massachusetts Institute of Technology and the University of Paris, honorary degrees of Doctor of Engineering were conferred upon Doctor Burgess by Case School of Applied Science in 1923 and Lehigh University in 1925.

Doctor Burgess was married on January 5, 1901, to Suzanne Babut of Paris, France, who survives him. He had no children.

Funeral services were held in Washington, D. C., at All Souls Unitarian Church at five o'clock on the afternoon of July 4. Interment took place at Newton, Mass., on July 5.

CONFERENCE OF STATE UTILITY COMMISSION ENGINEERS.

The tenth annual conference of State utility commission engineers was held at the bureau on June 2 and 3, 1932. One or more engineers were present from the District of Columbia and each of the following States: Connecticut, Illinois, Iowa, Maryland, North Dakota, New Jersey, New York, West Virginia, Vermont, and Wisconsin. J. Howard Mathews,

chief engineer, Commerce Commission, Illinois, was chairman of the conference.

The papers presented covered the following subjects: (1) Methods of grounding electric circuits, including lightning-arrester grounds, Russell G. Warner, Connecticut; (2) Rural electrification standards, J. H. Mathews, Illinois; (3) Potatoes and therms, E. R. Weaver, Bureau of Standards; (4) Liquefied petroleum gas in the gas industry, M. T. Bennett, Wisconsin; (5) Scope of work, methods, and personnel of commission engineering department, J. Franklin Meyer, Bureau of Standards; (6) Uniform rules for bus operation, E. I. Rudd, Connecticut; (7) Cost and reliability of Diesel engine operation for small utilities, George Charlesworth, Iowa; (8) Grade-crossing protection, J. G. Hunter, California. Copies of all the papers available have been sent to the engineering departments of public service commissions not represented at the conference. Other commissions interested may obtain the papers upon application to the secretary of the conference. Permission to publish any of the papers must be obtained from the author of the paper.

The conference selected the following members as an executive committee to arrange a program and select the time for the annual conference to be held in 1933: E. I. Rudd, chairman, Connecticut; R. H. Nexsen, vice chairman, New York; Harry Barker, Vermont; M. T. Bennett, Wisconsin; I. L. Reynolds, District of Columbia; and J. Franklin Meyer, secretary, Bureau of Standards.

PHYSICAL PROPERTIES AND WEATHERING CHARACTERISTICS OF SLATE.

A paper based on laboratory studies and field inspections of the commercial slates during the past four years will appear in the September number of the *Journal of Research*. The laboratory studies covered tests on about 343 samples from nine States. Field studies included the collection of 60 samples of weathered slate from buildings ranging in age from 12 to 130 years.

Physical determinations include flexural strength, elasticity, toughness, abrasive hardness, absorption, porosity, density and resistance to various conditions of weathering.

Average values obtained for various properties are as follows:

Modulus of rupture	11,700 lbs./in.²
Elasticity in flexure (E)	13,500,000 do
Toughness	0.192 inch
Abrasive hardness (H_a)	7.6
Absorption (by wt.)	0.27 per cent.
Porosity	0.88 do
Bulk density	2.771
Wt. per cu. ft.	172.9 pounds

Toughness was determined as the maximum deflection of a specimen 3/16 inch thick when supported on two knife edges 16 inches apart and loaded through a third knife edge at the middle. Abrasive hardness was obtained by grinding under controlled conditions on a cast iron disc with No. 60 artificial corundum. The value "H_a" is computed as the reciprocal of the volume abraded. In comparison with other materials slate is somewhat harder than the oolitic limestones but softer than most marbles.

Great differences in weather resistance were found for some of the materials, this factor depending more on the mineral composition than on the physical properties. Slates containing both calcite and pyrite are not apt to give long service where exposed to weather. Such slates may even show decay under some conditions when used for interior purposes. The process causing decay was found to be the conversion of calcite to gypsum, in which sulphur from the pyrite and oxygen from the air supply the necessary elements. The increase in molecular volume produces internal stresses in the slate sufficient to cause disintegration. Heat and moisture conditions accelerate this action hence slates affected by this type of weathering may prove less durable in warm climates than cold.

Weathering test procedures suitable for determining the relative durability of various slates have been developed which may form a logical basis for slate specifications.

HIDING POWER OF PAINT.

A new board to be used in determining the hiding power of paint has been constructed. This consists of 18 white and 18 black, opaque, glass squares (4 inches square), laid

together in checkerboard fashion. In order to get the top surface as level and uniform as possible, the glass squares were laid face down on a smooth level surface (a piece of plate glass), and the cement placed on the backs of the glass squares, thus building up from the back of the squares. A layer of neat cement was laid next to the squares, followed by a 3 to 1 sand-Portland cement mortar. After waiting for two weeks for the cement to harden, the board was turned over, face side up, resulting in an excellent surface for brushing and applying paint. The area of the board is four square feet. The reflection factor of the white squares is 87 per cent., and the black squares 5 per cent. The squares of glass are so laid that no edge or frame hampers the brush in sweeping across the entire surface of the board. The board may be used for either dry or wet hiding power.

EFFECT OF PROTECTIVE COATINGS ON ENDURANCE PROPERTIES OF STEEL.

The effect upon the resistance of metals to fatigue, of coating them with some other metal, depends upon the nature of the bond between the metal and the coating, as explained in Research Paper No. 454, which will be published in the July number of the *Bureau of Standards Journal of Research.*

It has been shown by numerous investigations that the surface condition of a metal is a very important factor in determining its resistance to repeated stresses. Surface alterations caused by corrosion, either previous to or coincident with stressing are known to cause a marked lowering of the normal endurance limit of a metal. Metallic coatings are widely used to protect iron and steel from corrosion and it has been shown that such coatings may appreciably improve the resistance of metals to simultaneous stress and corrosion.

It is of interest to know what effect protective metallic coatings may have upon the endurance limit of metals when corrosion is not involved. A study has recently been made at the bureau of the effect of hot-dipped galvanized coatings and of electrodeposited zinc coatings upon the endurance limits of three ferrous materials: open hearth ingot iron containing 0.02 per cent. carbon and two plain carbon steels containing 0.45 per cent. and 0.72 per cent. carbon.

Endurance limits were determined on specimens of each material that were: (1) polished but uncoated; (2) galvanized by the hot-dip process; (3) zinc electroplated; and (4) acid pickled as for galvanizing. The ingot iron was tested in the hot rolled condition. Both of the carbon steels were tested in the normalized and annealed, in the quenched, and in the tempered conditions. Fatigue tests of the galvanized and the uncoated specimens were made on both R. R. Moore rotating beam, and on Haigh axial loading fatigue, testing machines. The acid pickling caused a decrease in endurance limit of as much as 40 per cent., the greatest decrease occurring in the quenched steels. The presence of a galvanized coating caused a still greater decrease in most of the materials, the maximum, 42.5 per cent., being obtained in the quenched or the tempered steels. The endurance limits of the electroplated materials were equal to or greater than those of the polished, uncoated materials.

The difference in the effects caused by the two types of coating is believed to be a result of the differences in the nature of the bond between zinc and steel and differences in structure and hardness of the two coatings.

THERMAL EFFECTS IN ELASTIC AND PLASTIC DEFORMATION.

In a paper by M. F. Sayre attention is called to the fact that when a material is subjected to a compressive stress the temperature rises, and when it is subjected to a tensile stress the temperature drops. This thermal effect is independent of any elastic defect in the material, but due to it alone, errors of 0.2 per cent. are possible in measuring loads with elastic calibrating devices. Present specifications for the use of elastic calibrating devices do not adequately cover the question of time limits necessary to keep the errors caused by thermal effects within the limits required by the specifications.

For the past few years the bureau has been certifying that proving rings meet a specification which requires an accuracy of one tenth of one per cent. at capacity load. At the time experiments were first started with proving rings it was found that if a ring could pass an overload test of 10 per cent.

satisfactorily, no errors as great as one tenth per cent. would be caused by elastic creep, elastic drift, and set. No provision was made to avoid the thermal effects mentioned because a rough estimate indicated that the temperature equalization would take place very rapidly. This was verified by the behavior of all rings up to 100,000 lb. capacity.

Because it was felt that Sayre's paper might cause undue suspicion of elastic calibrating devices, the time lag on a 300,000 lb. capacity proving ring was measured by means of a 10 : 1 lever system using a Last Word dial. Motion pictures of the dial and a stop watch were taken. The curve obtained shows the half creep time for a ring of this capacity to be about 13 seconds, and the three quarter creep time to be about 33 seconds. These values are in good agreement with the theory. It takes only about 50 seconds for the effect to disappear to within the experimental error of reading the ring.

The 300,000 lb. capacity proving rings are the largest the bureau has yet calibrated. It is pointed out that even for them no special precaution is necessary. It is also shown that $3b^2$ (inches^2) seconds gives with sufficient accuracy the approximate half-creep time of the thermal creep for a carbon or low alloy steel bar suddenly bent, where b is the thickness of the bar. Sayre's value, $10b^2$ (inches^2) seconds is considerably too large.

USE OF ALPHA-BENZOINOXIME IN THE DETERMINATION OF MOLYBDENUM.

Present procedures used for the determination of molybdenum, except the colorimetric method which is applicable to only small amounts, require a number of tedious and time-consuming operations before the actual determination of that element can be accomplished. It has been found at the bureau that when alpha-benzoinoxime, a reagent originally proposed for the determination of copper, is added to cold sulphuric, hydrochloric, or nitric acid solution of sexivalent molybdenum, not only is molybdenum quantitatively precipitated but it is readily separated from a large number of other elements such as copper, lead, bismuth, tin, arsenic,

antimony, iron, titanium, chromium, vanadium and many others. Tungsten and palladium, which are also quantitatively precipitated by the reagent should be removed, if present, before attempting the precipitation of molybdenum. The interference of silicon and tantalum is of no great importance and can easily be avoided. As applied to ores and similar material, precipitation with alpha-benzoinoxime is effected directly after removal of lead, silica, etc., by dehydrating with sulphuric acid. The resulting precipitate, after appropriate washing, is dried, ignited, and weighed as molybdenum trioxide. The ignited oxide is dissolved in dilute ammonium hydroxide, acidified with hydrochloric acid and treated with cinchonine. Any resulting precipitate of tungsten is filtered, ignited, weighed, and deducted from the weight of molybdic oxide already obtained. In the case of steel, precipitation is made directly after solution and oxidation of the sample by means of sulphuric and nitric acids. The treatment of the precipitate is the same as that outlined for ores.

This method will be described in detail in Research Paper No. 453 in the July number of the *Bureau of Standards Journal of Research*.

EXPANSION FACTOR FOR ORIFICE METERS.

The discharge coefficient of an orifice meter, determined with water, is applicable when the meter is used for measuring the flow of a gas, provided that the differential pressure is so small that the accompanying change of density is insignificant. But if the differential is a considerable fraction of the absolute static pressure, the water coefficient must be multiplied by an "expansion factor" which allows for the effects of change of density.

Research Paper No. 459, which will be published in the July number of the *Bureau of Standards Journal of Research*, contains a discussion of recent experimental data which show how the expansion factor depends on the form of the meter, the ratio of downstream to upstream pressure, and the specific heat ratio of the gas. The conclusions are summarized

in an empirical equation which may be used for computing the value of the expansion factor in certain practically important cases.

A theoretical method of computing the expansion factor is developed and is shown to agree reasonably well with the facts observed under conditions that are approximately in accordance with those postulated by the theory.

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LIBRARY NOTES.

RECENT ADDITIONS.

BARR, GUY. A Monograph of Viscometry. 1931.

Beilsteins Handbuch der organischen Chemie. Vierte Auflage. Erstes Ergänzungswerk. Neunter Band. 1932.

CARTER, THOMAS FRANCIS. Invention of Printing in China and Its Spread Westward. 1931.

CLEAVES, MARGARET A. Light Energy: Its Physics, Physiological Action and Therapeutic Applications. 1904.

CLODD, EDWARD. The Story of the Alphabet. 1930.

GUNTHER, R. T. Early Science in Oxford. Volume IX: De Corde, by Richard Lower, London, 1669; with Introduction and Translation by K. J. Franklin. 1932.

HODGINS, ERIC, AND F. ALEXANDER MAGOUN. Behemoth: the Story of Power. 1932.

Hoyer-Kreuter Technological Dictionary. Sixth completely revised edition, edited by Alfred Schlomann. Volume 2: English-German-French. 1932.

LOEB, LEONARD B. The Nature of a Gas. 1931.

NEWMAN, F. H. Recent Advances in Physics (Non-Atomic). 1932.

Organic Syntheses. Collective Volume I. Being a revised edition of annual volumes I–IX. 1932.

OSWALD, JOHN CLYDE. Benjamin Franklin. Printer. 1917.

PAUL, J. HARLAND. The Last Cruise of the Carnegie. 1932.

SMITH, HORATIO DAVIS. Early History of the United States Revenue Marine Service or United States Revenue Cutter Service 1789–1849. 1932.

ULLMANN, FRITZ. Enzyklopädie der technischen Chemie. Zweite, völlig neubearbeitete Auflage. Bd. 1–9. 1928–1932.

Wien-Harms Handbuch der Experimentalphysik. Bd. XI, 1 Teil: Elektrodynamik, von Gustav Mie. 1932.

WILLIAMS, ARCHIBALD. The Romance of Modern Mechanism. 1907.

BOOK REVIEWS.

RECENT ADVANCES IN PHYSICS (NON-ATOMIC), by F. H. Newman, D.Sc., A.R.C.S., F.Inst.P., Professor of Physics, University College of the South-West of England, Exeter. ix–378 pages, 13 x 20 cms., illustrations. Philadelphia, P. Blakiston's Son & Co., Inc., 1932. Price $4.00.

To keep informed on the profound advances which are taking place in the fundamentals of physical science is an arduous task. From every quarter, where physical science is investigated, come innumerable papers which deal

with every angle of the subject. Many of them relate to those theorems of atomic character which have yielded theoretically valuable and practically applicable results. Others are on the more familiar ground of new refinements in the examination of phenomena which are representative of the long-established physics of yesteryear. The list is a formidable one. Some 4,000 papers, the author says, are published annually and rare discrimination is entailed in making a representative selection that may be included within the covers of a single small volume.

The non-atomic part of the work is represented by high-pressure effects, surface tension, adsorption, and viscosity, acoustics, and electro-acoustics, and the measurements and effects of low temperatures. The chapters, in which electronic and atomic considerations enter are: the wave-like character of matter, statistical mechanics, electromagnetic radiations, magnetism, and electricity. This choice of topics, which is mostly representative of fundamental processes, seems eminently adapted to the need of readers who desire a guide to study or condensed information. Of especial value, is the copious collection of bibliographic lists and periodical references.

L. E. P.

EXAMINATION OF WATER, CHEMICAL AND BACTERIOLOGICAL. By William P. Mason. Sixth edition, revised by Arthur M. Buswell. 224 pages, 15.5 x 23.5 cm., illustrated. New York, John Wiley and Sons, Inc., 1931. Price $3.00.

Fourteen years have elapsed since the Fifth Edition of this work appeared. It is therefore good to see an old and practicable guide brought up to date, especially since this is in a field that relatively has been neglected.

Among the changes to be noted in the revision are the addition of methods for the determination of pH and free chlorine. Losses due to hard water are more adequately discussed and detailed directions for the systematic analysis of boiler waters have been added, as well as three laboratory experiments relating to water treatment. The appendices have been enlarged so that they now occupy 55 pages, giving useful data relating to permanent standards for use in the analysis of water, problems in the interpretation of bacterial tests, forms for recording water purification data, and U. S. Treasury standards for drinking and culinary water which include valuable summaries of the considerations relative to source, bacteriological quality and physical and chemical characteristics.

To those unfamiliar with the older editions it may be said that this is intended to be a text book principally supplying the needs of the undergraduate student rather than those of the experienced water chemist, but the arrangement of the subject matter is rather unconventional for a text book. The presentation frequently reflects the extensive background of the authors but is nevertheless direct in method and without waste of words either in the running text or in the numerous procedures. In fact, a good analytical background is assumed and the principles, limitations, variations and usual precautions are largely taken for granted.

A considerable variety of procedures is offered, supplying practically any type of examination needed, whether for field survey, rapid laboratory examination,

more accurate mineral water analysis, or boiler water analysis, etc. The procedures supplement but do not take the place of the standard methods of the A.P.H.A. or A.O.A.C. Specific direct tests and short cuts are emphasized and these alone make the book a good investment for any laboratory which has any interests of this kind.

There are relatively few inaccuracies, one being found on page 14, line 9, where the factor should be 10, not .10. The reviewer is decidedly skeptical of the accuracy of the colorimetric method for silica (page 113), having found in his own experience that there are many factors entering into this determination not to be found in the literature. In fact he is doubtful whether this method is worthy of place in water analysis procedures, in spite of its speed and apparent simplicity. In his experience also he has found picric acid to be a much more satisfactory color standard than potassium chromate. The second sentence under "Sodium Calculation" on page 118 contains a misstatement.

In general the new edition can be recommended for its directness, its reliability and its comprehensiveness. It is by no means a treatise on water examination, however, and especially is this true of bacteriological and microscopical examinations, a department which might well be expanded.

LESLIE R. BACON.

MEET THE SCIENCES, by William Marias Malisoff, 196 pages, 14.5 x 22 cms. Baltimore, The Williams & Wilkins Company, 1932. Price $2.50.

Not even so few as three times has the reviewer mentally kicked himself for presuming to write about this book. At the risk of discouraging one prospective reader for the sake of quickening the interest of a score of others, your humbled servant confesses to having read the book twice and realizes that for his own good once more would not be going to excess. After the back cover had been closed down upon the Glossary and the "Sans Tache" of the publishers for the second time, the difficult part of the task was only begun. Some way must be found to convey to the reader a true and unbiased description of this product of an author's labor.

Without a doubt, an author is best fitted to summarize the nature of his book. This he often does under the title of Foreword or Preface. How truthful has been his description can only be determined after his work is read. In their announcement, the publishers have wisely included the author's Foreword and we, swallowing our pride, beg to do likewise. "A panoramic view of the sciences is the specific aim of this work. The book is for the layman, but not for all laymen. There are too many varieties. The author is very serious and expects the reader to be serious. The reader helps write the book by the quality of the attention he gives it. The relaxation of a Turkish bath is hardly to be expected in a responsible survey of a highly developed field of human thought. The author's hopes are reflected in his plan. First, he introduces the scientist in a general way. Second, he presents the round-table of the sciences. Third, he treats the major sciences individually in three groups. Fourth, he allows himself to comment on the place of science in modern life. What may one expect from this? For the scientist—a more tolerant understanding; for science—a clearer conception of its humble aims and human value; for the individual sciences—the beginning of an acquaintance that must end in friendship."

Of necessity the author must don the mantle of the philosopher in order to accomplish his ambitious task. His brief outlines of historical development and critical appraisements of each science's accomplishments and fulfillments of purpose indicate drinking deeply at the "Pierean spring." Before going further, it should be pointed out that in view of the author's statement his book was written for the serious layman, all scientists with a philosophical turn of mind should read "Meet the Sciences" for their delectation, while those not so inclined should read it anyway in the hopes their outlook shall be widened pleasurably. To avert any possible feelings of disappointment occurring to the unsuspecting reader let him be warned that the author has used few words unnecessarily. Good solid fare extends from cover to cover and a casual perusal can result in nothing more than a bad case of mental indigestion. Chapters could be written in pointing out pithy statements, interesting facts and stimulating conclusions, but why not each man for himself?

T. K. CLEVELAND.

REVUE D'ACOUSTIQUE. A journal appearing six times per year. Vol. I, No. I, xi–84 pages, 16 x 23 cms., edited by J. Brillouin, R. Lucas, and A. Marcelin. Paris, Les Presses Universitaires de France, 1932. Price, yearly, 125 francs, single numbers 25 francs.

There are few periodicals, if any, which deal exclusively with acoustics, yet the subject has achieved a most important position in recent years. Thermionic methods have greatly facilitated the study of sound, and the control of sound-frequency components is readily effected, and satisfactory rendition in auditory apparatus insured. The telephone, the phonograph and radio have undoubtedly contributed vastly to the now industrial prominence of acoustics, but in the more or less separate field of architectural acoustics, the acoustical properties of a hall or a theatre is no longer a matter of precedent or chance. The appearance of this journal is accordingly a timely index of the arrival of this important science into the realm of engineering subjects.

The subject-matter of the initial number is wisely chosen, as might be expected from the distinguished personnel of the *Comite de Direction*. The first article by M. F. Canac is Acoustic Terminology. Scarcely a more suitable subject could be chosen for the first article of the initial number. M. Jean Perrin, under Acoustic Receivers, analyzes the air-pocket type of receiver (*capsules acoustique*) and its variants. The well-known "geophone" with which are associated the names Chilowski, A. Marcelin, Labrousti, and Jonaust in the service of General Ferrie is discussed. M. Carriere contributes Absolute Measure of Fundamental Magnitudes in Acoustics; frequencies, amplitudes, velocities, pressures. M. F. Canac in Determination of the Coefficient of Absorption in Tubes; rubber tubes, reinforced rubber tubes, and metallic tubes.

The number concludes with sections of abstracts and bibliography. The *Revue* is a worthy and welcome addition to current scientific literature.

LUCIEN E. PICOLET.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS:

Report No. 422, Wind-Tunnel Research Comparing Lateral Control Devices, Particularly at High Angles of Attack. II. Slotted Ailerons, and Frise Ailerons, by Fred E. Weick and Richard W. Noyes, 16 pages, illustrations, 23 x 29 cms. Washington, Superintendent of Documents, 1932.

Three model wings, two with typical slotted ailerons and one with typical Frise ailerons, have been tested as part of a general investigation on lateral control devices, with particular reference to their effectiveness at high angles of attack, in the 7 by 10 foot wind tunnel of the National Advisory Committee for Aeronautics. Force tests, free-autorotation tests, and forced-rotation tests were made which show the effect of the various ailerons on the general performance of the wing, on the lateral controllability, and on the lateral stability. In general, the slotted and Frise ailerons tested were inferior in rolling control at 20° angle of attack to plain ailerons of the same size. The adverse yawing moments obtained with the slotted and Frise ailerons were, in most cases, slightly smaller than those obtained with plain ailerons of the same size and deflection. However, this improvement was small as compared to the improvement obtainable by the use of suitable differential movements with any of the ailerons, including the plain.

Report No. 423, Wind-Tunnel Research Comparing Lateral Control Devices, Particularly at High Angles of Attack. III. Ordinary Ailerons Rigged up 10° when Neutral, by Fred E. Weick and Carl J. Wenzinger, 12 pages, illustrations, 23 x 29 cms. Washington, Superintendent of Documents, 1932.

Wind-tunnel tests have been made on three model wings having different sizes of ordinary ailerons rigged up 10° when neutral, the same models having previously been tested with the ailerons rigged even with the wings in the usual manner. One of the wings had ailerons of medium size, 25 per cent. of the wing chord by 40 per cent. of the semispan, one had long, narrow ailerons, and one had short, wide ones. These tests are part of a general investigation on lateral control devices, with particular reference to the control at high angles of attack, in which all the devices are being subjected to the same series of tests in the 7 by 10 foot wind tunnel of the National Advisory Committee for Aeronautics. Force tests of the usual type, free-autorotation tests, and forced-rotation tests were made showing the effect of the ailerons on the general performance of the wing, on the lateral controllability, and on the lateral stability.

With the ailerons rigged up 10° when neutral, negligibly small yawing moments (body axes), at all angles of attack which can be maintained by conventional airplanes, were given by the medium-sized ailerons with equal up-and-down deflection. Large favorable yawing moments, and no adverse ones with any portion of the total deflection, were given at all angles of attack by each of the three sizes of ailerons with up-only movement, by the short, wide ailerons with a medium differential movement, and by the medium-sized ailerons with an extreme differential movement. The direct rolling control was best at high angles of attack with the short, wide ailerons with an extreme differential movement, but this combination required exceptionally high control forces. For neutral setting the lateral instability was found to be less with the ailerons rigged up 10° than with them rigged even with the wing.

PUBLICATIONS RECEIVED.

Modern Materials Handling, by Simeon J. Koshkin, 488 pages, illustrations, tables, 15.5 x 23.5 cms. New York, John Wiley & Sons, Inc., London, Chapman & Hall, Ltd., 1932. Price $6.00.

Theorie de la Quantification dans la nouvelle Mecanique, par Louis de Broglie, 250 pages, 16.3 x 25 cms. Paris, Hermann et Cie., 1932. Price 70 francs.

L'Idee Generale de la Mecanique Ondulatoire et de ses premieres applications, par Marcel Boll, 74 pages, 14 x 20 cms. Paris, Hermann et Cie., 1932. Price 15 francs.

Expose Electronique des Lois de l'Electricité, par Marcel Boll, 72 pages, illustrations, 14.2 x 22.5 cms. Paris, Hermann et Cie., 1932. Price 15 francs.

Actualites Scientifiques et Industrielles, Exposés de Physique Theorique, Sur Une Forme Plus Restrictive des Relations d'Incertitude, D'apres MM. Landau et Peierls, par Louis de Broglie, 24 pages, 16 x 25.5 cms. Paris, Hermann et Cie, 1932. Price 6 francs.

La Projection de Noyaux Atomiques par un Rayonnement tres Penetrant, l'Existence du Neutron, par Irene Curie et F. Joliot, 22 pages, plates, illustrations, 16.5 x 25.5 cms. Paris, Hermann et Cie., 1932. Price 6 francs.

Experimental Physics for Colleges, by Walter A. Schneider and Lloyd B. Ham, 259 pages, illustrations, 14.5 x 22 cms. New York, The Macmillan Company, 1932. Price $2.25.

U. S. Bureau of Mines, Mineral Resources of the United States, 1929, by O. E. Kiessling, Part 1—Metals, 968 pages, tables, 15.5 x 23.5 cms. Washington, Government Printing Office, 1932. Price $1.50 (cloth). Bulletin 353, Tests of Rock-Dust Barriers in the Experimental Mine, by George S. Rice, H. P. Greenwald and H. C. Howarth, 81 pages, tables, illustrations, 15 x 23 cms. Washington, Government Printing Office, 1932. Price ten cents. Technical Paper 516, Natural Ventilation of Michigan Copper Mines, by G. E. McElroy, 40 pages, illustrations, tables, 15 x 23 cms. Washington, Government Printing Office, 1932. Price five cents. Technical Paper 520, Falls of Roof and Coal in Mines Operating in the Sewickley Coal Bed in Monongalia County, W. Va., by J. W. Paul and J. N. Geyer, 31 pages, illustrations, tables, Washington, Government Printing Office, 1932. Price five cents.

Combustion, a reference book on theory and practice, third edition, 208 pages, illustrations, 22.5 x 30 cms. New York, American Gas Association, 1932. Price $2.00.

U. S. Coast and Geodetic Survey, Special Publication No. 175, First and Second Order Triangulation in Oregon, by Clarence H. Swick, 88 pages, plates, tables, illustrations, 15 x 23 cms. Washington, Government Printing Office, 1932. Price ten cents.

Bell Telephone Laboratories, Monographs: No. B-669, Fatigue Studies of Telephone Cable Sheath Alloys—II, by J. R. Townsend and C. H. Greenall, 9 pages, illustrations, 15.2 x 23 cms. No. B-670, Magnetic and Mechanical Hardness of Dispersion Hardened Iron Alloys, by K. S. Seljesater and B. A. Rogers, 20 pages, tables, illustrations, 15.2 x 23 cms. No. B-671, Two Problems

in Potential Theory, by Thornton C. Fry, 11 pages, illustrations, 15.2 x 23 cms. No. B-672, The Problem of Projecting Motion Pictures in Relief, by Herbert E. Ives, 23 pages, illustrations, 15.2 x 23 cms. No. B-673, Application of Quartz Plates to Radio Transmitters, by O. M. Hovgaard, 16 pages, illustrations, 15.2 x 23 cms. New York, 1932.

National Advisory Committee for Aeronautics, Technical Notes, No. 417, Wind-Tunnel Tests of a Hall High-Lift Wing, by Fred E. Weick and Robert Sanders, Langley Memorial Aeronautical Laboratory, 4 pages, diagrams, 19 x 26 cms. Washington, Committee, 1932. No. 419, Wind-Tunnel Tests of the Fowler Variable-Area Wing, by Fred E. Weick and Robert C. Platt, Langley Memorial Aeronautical Laboratory, 6 pages, tables, diagrams, 19 x 26 cms. Washington, Committee, 1932. No. 421, The Nature of Air Flow about the Tail of an Airplane in a Spin, by N. F. Scudder and M. P. Miller, Langley Memorial Aeronautical Laboratory, 6 pages, illustrations, 19 x 26 cms. Washington, Committee, 1932. No. 423, Effect of Length of Handley Page Tip Slots on the Lateral-Stability Factor, Damping in Roll, by Fred E. Weick and Carl J. Wenzinger, Langley Memorial Aeronautical Laboratory, 6 pages, tables, illustrations, 19 x 26 cms. Washington, Committee, 1932.

CURRENT TOPICS.

Protecting Food with Colored Wrappers.—(U. S. Dept. of Agric. Clip Sheet No. 729.) Most colored transparent materials permit the passage of the rays of light that promote food spoilage. Only two—grass green and black—shut out those rays, the green, like the chlorophyll of plants, by absorbing the photochemically active wave-lengths of light and the black by absorbing practically all the rays. In one test two lots of the same meal were stored side by side for about a year, one in a glass bottle exposed to the direct sunlight and the other in a glass bottle wrapped in black paper. The meal in the wrapped bottle was fresh and sweet when removed; that in the unprotected bottle was spoiled and had a very rancid odor.

In another test a set of vials, one containing lard, one butter, and one salad oil, was placed in each of 10 compartments. Each compartment was covered with glass of a different shade and the whole frame was exposed to sunlight. At the end of the experiment the material kept under the grass-green glass was still sweet while that kept under the glass of any other shade of green, as well as of the different shades of blue, purple, yellow, orange, and red, was distinctly rancid. The same results were obtained when oil-bearing foods were wrapped in cellophane of varying hues.

T. K. C.

The Production of High Speed Light Ions without the Use of High Voltages.—(*Physical Review*, **40**, 19.) The problem of disrupting the nucleus of an atom as approached by the physicist is quite similar to that encountered by the maker of armor-piercing bullets and shells. Thus, for a projectile of given mass its penetrating power is proportional to its velocity. Likewise, the resistance of the atom to a cataclysmic penetration of an ion can be overcome only when this charged particle possesses a relatively high velocity. Such velocities are acquired by ions when brought under the influence of an electrical potential gradient usually measured in volts. That an ion shall have a velocity rendering it capable of smashing an atom, these potential gradients should be in excess of 1,000,000 volts. Many of us have seen in picture or reality arrangements of what seemed to be enormous x-ray tubes designed to produce charged particles having velocities equivalent to 900,000 volts or more.

This straightforward method of accelerating ions through the requisite differences of potential presents great experimental difficulties associated with the high electric fields necessarily involved. And so, E. O. Lawrence and M. S. Livingston, University of California, report a method that avoids these difficulties by means of the multiple acceleration of ions to high speeds without the use of high voltages. Briefly, the method is as follows: Semi-circular hollow plates are mounted with their diametral edges adjacent, in a vacuum and in a uniform magnetic field that is normal to the plane of the plates. High frequency oscillations are applied to the plate electrodes producing an oscillating electric field over the diametral region between them. As a result during one half cycle the electric field accelerates ions, formed in the space separating the two plates, into the interior of one of these electrodes where they are bent around on circular paths by the magnetic field and eventually emerge again into the region between the electrodes. The magnetic field is adjusted so that the time required for traversal of a semi-circular path within the electrodes equals a half period of the oscillations. In consequence, when the ions return to the region between the electrodes, the electric field will have reversed direction and the ions thus receive second increments of velocity on passing into the other electrode. Because the path radii within the electrodes are proportional to the velocities of the ions the time for traversal of the semi-circular path is constant and if the ions take exactly one half-cycle on their first semi-circles, they do likewise on all succeeding ones and therefore spiral around in resonance with the oscillating electric field until they reach the periphery of the apparatus. Their final kinetic emergies are as many times greater than that corresponding to the voltage applied to the electrodes as the number of times they have crossed from one electrode to the other. Using a magnet with pole-face 11 inches in diameter, a current of 10^{-9} ampere of 1,220,000 volt-protons has been produced in a setup to which the maximum applied voltage was only 4000 volts. These present experiments indicate that this indirect method of multiple acceleration now makes practicable the production of protons having kinetic energies in excess of 10,000,000 volt-electrons.

T. K. C.

Frank Julian Sprague.—On July 25 men prominent in the fields of engineering and science met to pay tribute to Frank Julian Sprague: scientist, inventor, engineer, "father of electric traction." Mr. Sprague, thus honored on his 75th birthday, was born in Milford, Conn., July 25, 1857. He attended the U. S. Naval

Academy 1874–8 and resigned from the U. S. Navy, 1883. After filling the role of assistant to Thomas A. Edison for one year he became actively connected with electric railway transportation systems and has taken a prominent part in their expansion. A recent notable accomplishment has been the development of the dual elevator system. Recipient of the Franklin Institute Eliott Cresson and Franklin medals, the Edison medal of the A.I.E.E. as well as degrees from Stevens, Columbia, and Pennsylvania, this guest of honor is hailed as a pioneer who personifies vision, persistence, courage, energy and zeal—an unsurpassed example.

T. K. C.

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AWARDS BY THE INSTITUTE

The following awards are made by The Franklin Institute:

The Franklin Medal (Gold Medal).—This medal is awarded annually from the Franklin Medal Fund, founded January 1, 1914, by Samuel Insull, Esq., to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance a knowledge of physical science or its applications.

The Elliott Cresson Medal (Gold Medal).—This medal is awarded for discovery or original research, adding to the sum of human knowledge, irrespective of commercial value; leading and practical utilizations of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes, or unusual skill or perfection in workmanship.

The Howard N. Potts Medal (Gold Medal).—This medal is awarded for distinguished work in science or the arts; important development of previous basic discoveries; inventions or products of superior excellence or utilizing important principles.

The George R. Henderson Medal (Gold Medal).—This medal is to be awarded for meritorious inventions or discoveries in the field of railway engineering.

The John Price Wetherill Medal (Silver Medal).—This medal is awarded for discovery or invention in the physical sciences or for new and important combinations of principles or methods already known.

The Edward Longstreth Medal (Silver Medal).—This medal is awarded for inventions of high order and for particularly meritorious improvements and developments in machines and mechanical processes. In the event of an accumulation of the fund for medals beyond the sum of one hundred dollars, it is competent for the Committee on Science and the Arts to offer from such surplus a money premium for some special work on any mechanical or scientific subject that is considered of sufficient importance.

The Louis E. Levy Medal (Gold Medal).—This medal is awarded to the author of a paper of especial merit, published in the JOURNAL OF THE FRANKLIN INSTITUTE, preference being given to one describing the author's experimental and theoretical researches in a subject of fundamental importance.

The Walton Clark Medal (Gold Medal).—This medal is awarded to the "author of the most notable advance in knowledge or improvement in apparatus, or in method concerning the science or the art of gas manufacture or distribution or utilization in the production of illumination, or of heat, or of power."

The Certificate of Merit.—A Certificate of Merit is awarded to persons adjudged worthy thereof for meritorious inventions, discoveries or improvements in physical processes or devices.

The Boyden Premium.—Uriah A. Boyden, Esq., of Boston, Mass., has deposited with The Franklin Institute the sum of one thousand dollars, to be awarded as premium to "any resident of North America who shall determine by experiment whether all rays of light and other physical rays are or are not transmitted with the same velocity."

For further information relating to these awards apply to the Secretary of the Institute.